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PROJECTS OF THE FLOOD CONTROL, NAVIGATION AND IRRIGATION FOR THE HUAI RIVER SYSTEM

HUAI RIVER COMMISSION

1930

PREFACE

The project of the regulation of the Huai River, which embraces large parts of Kiangsu, Shangtung, Anwhei and Honan, destined to exercise a profound effect upon the livelihood of millions of people. After the Central Executive Committee of the Kuomingtang passed, during the Second Plenary Session, the resolution to complete in five years the necessary work which is based on the data and maps procured in the past eighteen years, the National Government took to appoint the Huai River Commission and set forth basic principles and instruction with the purpose of carrying out the plan within the allotted time limit. The anxiety of the Central Government over the living conditions of the people dwelling in the Huai River valley should be honestly appreciated.

In order to make a good beginning no effort was spared in the elaboration of a working plan. With the general schemes as hitherto outlined by scholars and engineers becoming more or less out of date, resurveying work had to be undertaken. Specialists were therefore enlisted and in due course of time, two surveying parties were organized and sent out to the fields. Under the direction of the Chief Engineer, an inspection party traversed many localities in the valleys of the Huai River, the Grand Canal, Yi Ho, Shu Ho, Wen Ho, Sze Ho and the Yellow River. After one year's continuous effort and steady working, the Chief Engineer was eventually able to draw up the report .

No.1 which gives projects of flood control, navigation, and irrigation for the Huai River System, and is illustrated profusedly with diagrams and drawings. The Commission then decided to convene a special conference to give a final touch to the gigantic project and to this conference come pepresentatives of the four Provincial Governments, the National Reconstruction Commission, the Yangtse River Commission, the Famine Relief Committee, and several specialists particularly interested in the conservancy problem of the Huai River, together with the members and engineers of the Commission. After a lengthy discussion the report was formally adopted whereupon the Commission submitted it to the National Government. As soon as necessary fund is raised, the work will be carried out.

To sum up, the flood problem of the Huai River Valley has long been a source of serious concern and much has been said to solve it, but due to financial difficulty solution work had to be postponed from time to time. Moreover, the "Easier said than done" attitude of certain people has always worked as a handicap. In this connection we believe in Dr. Sun Yat-sen's statement "Harder to know than to do". Now with the scheme having been duly prepared we shall endeavour to follow teachings in Dr. Sun's book on "International Development of China" and hope in the immediate future enough fund could be obtained to carry the great project to success, thus relieving forever the anxiety of the people in the Huai River Valley. On sending the report to press, I take the liberty to add these few paragraphs in the hope that my countrymen would give their hearty approval.

Chiang Kai-shek

Nanking, January, 1931.

Letter of Transmittal

Huai River Commission, Engineering Bureau,

Huaiyin, Province of Kiangsu,

May 31, 1930.

President Chiang, Kai-shek, Chairman,

and the Honorable Members of the Commission.

Nanking.

Sirs:

I have the honor to submit herewith the first number of official Technical Reports on the projects to effect the flood control and the improvement of navigation and irrigation of the whole Huai River system.

In last June, by the order of the National Government, I was appointed concurrently the Chief Engineer of this Commission and Commissioner of the Engineering Bureau. Seeing the heavy duties this imposed on me, and the Government's anxiety in the Nation's Reconstruction, I made every effort to enlist the services of the engineering specialists from different parts of the country. The office of the Bureau was successfully established in July in the Capital. Then I proceeded to Huaiyin to organize there the Chief Engineer's Office with its two departments, engineering and surveying. Two surveying parties were also subsequently formed and sent to the field. Afterwards, I went on an inspection tour with several engineers to examine at closehand the different rivers, including the Yangtzekiang, Huai

River, Yellow River, Grand Canal and the Yi, Shu, Wen, Sze River. In the meantime, the available topographical and hydrological data and records were carefully collected and analysed.

After grasping the general characteristics of the region under question, and the hydraulics of the Hungtze Lake, comparative estimates of different projects to send flood water of the Huai River either to the Yangtzekiang or the sea, were made. Surveying parties were also instructed to make surveys along the most possible routes contemplated.

On Nov. 20, 1929. Prof. Otto Franzius of Hannover University, the Consulting Engineer of the Commission, arrived at Nanking. I went with him to the important rivers and localities, and showed him all available maps and records. After holding conferences with our engineers, and carefully studied the problem, he was finally able to state his opinion as to the most economical and practical projects to effect the solution of the problem in his report. Based on his suggestions and the field data, the surveying work being finished in due course of time, and then further investigation and designs were made by my engineering staff. The result of the study is contained in the present report.

Part of the schemes are based upon the former records and maps, therefore they are subject to change when complete surveys are made. With the accomplishment of surveys and records of the far-sighted men in the past decade and the experiences of the foreign and native engineers, this report, it is hoped to set forth a right way to the solution of the problem on hand.

Respectfully submitted

H. Li(signed)

Chief Engineer and Commissioner.

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Chapter 1. General Statement

Article 1. Introduction

The deterioration of the natural lower course of the Huai River was not begun as commonly believed with the year 1852 when the Yellow River broke through its bank at Tung-wa-shian in the Province of Honan and migrated to the north. It was really due to, the gradual silting-up of its bed from the Hungtze Lake down to the sea and the admission of the Yellow River into it long ago. During the Ming and Ching Dynasties, nearly all the river authorities were busily engaged in elevating the water surface of the lake in order to reserve enough water to help the dilution of silt-burden water of the Yellow River, for if the lake were not elevated no water of the Huai River could enter the Yellow River at its outlet near Huaiyin. In the meantime the Huai River had, however, already made the San Ho down to the Yangtzekiang its main course of flood escapeway. The abandoned bed proved to be useless as soon as the migration of the Yellow River happened, as no single drop of water could ever pass through it at that time.

The first man called to public attention to regulate the Huai River was Mr. Ting-hsien of Sanyang. He did not succeed to get any support. The late Mr. Chang Chien was the most outstanding man to pay attention to the question. He established the Kiang Huai Conservancy Board, which was subsequently reorganized into the Huai River Surveying Board. This board lasted from 1912 to 1926, and had accomplished most of the surveying work. Besides this, the Huai Region has been surveyed to certain limit by the different organizations, such as Kiangsu Grand Canal Board, Huai-Yang-Hsu-Hai Topographic Surveying Board; Anhwei Conservancy Board and Shantung Grand Canal Board. For these reasons, the number of maps and records in this region is most abundant in comparison with other rivers of this country. It is the result of the continuous effort of the late farsighted men, to whom we should not pass without mentioning a word.

Many schemes have been drawn up by the engineers either in this country or abroad, such as the Red Cross Engineers' Report of 1914, John R. Freeman's Report of 1920, Kiang Huai Conservancy Board's Report, Anhwei Conservancy Board's Report and the former National Conservancy Bureau's Report. Mr. Wu Tung-chu of Kwanyung District wrote a great deal about the problem. His "Table of Annual Events of the Huai River Systems" is a piece of very laborious work.

It is due to the continuous fightings of the notorious generals in the country since the establishment of the Republic that the construction works of the regulation of the Huai River has not been able to carry out, inspite of the attention has paid to it. In 1928, the National Reconstruction Commission appointed a committee to make a collection of the literature and records of the Huai Regulation problem. A pamphlet called "Report on the Records and Maps in Connection with the Huai River Problem" was issued afterwards. The National Government finally paid its attention to this matter, and appointed in succession, in January, 1929 twenty members, to organize the Huai River Commission, with the President as the chairman. The three bureaus under the Commission, that is, the Bureau of General Affairs, the Bureau of Finance and the Bureau of Engineering, were established successively. Prof. Otto Franzius of Hannover University was invited to act as the consulting engineer, with a six month contract, and he arrived at Nanking on 20th, November of that year. Although rebellions have been broken out from time to time since the organization of the Commission, the Government has meanwhile spared no effort to the Nation's reconstruction work. The Commission was encouraged to push on its work for the Nation's benefit.

Tentative technical reports have been drawn up dealing with certain aspects of the problem, such as:

The Hydraulic of the Hungtze Lake,

Water Requirements below the Hungtze Lake,

Hungtze Lake as a storage and also a Flood Detention Reservoir,

Frequencyoof Floods of the Huai River,

Project of Escapeway through the Kao Pao Lakes for the Huai River,

Estimate of Excavation for a Channel in the Old Yellow River Bed,

Preliminary Estimates of Excavation of the Outlet to the Sea for the Huai River,

Project of Diverting Flood Water through the Sheyang Hu to the Sea, Memorandum on Shantung Grand Canal Project.

In each tentative project, paper location of different routes was made in order to compare the quantity of earthwork for the final selection. On seeing that the most possible poutes to divert the flood water of the Huai River are those by way of the Lao Pao Lakes and Kwan Ho, surveying parties were sent to those places. Topographic maps of 1:2,500 and 1:10,000 scales were made. Beside these detail surveys of the sites for regulators and locks at Chiangpa, Shaopai, Yangchuang etc., were also made. Borings were taken at each site of the contemplated structures to reveal the underground conditions. All those matters are connected to the final make-up of the scheme.

Prof. Franzius has also exerted all his effort and time in working up different projects, going along harmoniously with our engineers for the whole period of his staying in China. Even though he was prevented from visiting all the places in the Huai River territory on account of the distrubance of the rebellion, nevertheless, with the aid of the abundant maps and records of the region under question, and also the explainations of some of our engineering staff who are quite familiar with the local conditions, he was able to drew up a lengthy report, which is very complete in its nature. In his report, the flood control measures of the upper and middle Huai River together with the tributaries, the utilizations of the Huangtze and the Wishan Lakes, the construction of the outlet channel of the San Ho, the regulation of the Grand Canal, Salt Canal and Kwan Ho, the improvement of the Wen, Sze, Yi and Shu Rivers, and the schemes of navigation and irrigation, are all deliberately dealt with. Moreover he also wrote another report on the regulation of the Yellow River from all available data and records.

The principal part of the schemes in this report is the same as in his, since in working up the plan, much investigation and deliberation were exercised by our engineers in reaching the most economical and effective solution for both purposes. The only difference in the two reports consists in some numerical assumptions in calculations. As soon as the principle of the scheme is worked out, designing work begins accordingly, such as designs for the flood channel, movable dams, ship locks, etc., each being designed in different types and materials for comparison. For these reasons, as soon as this report is approved and adopted by the Commission, and fund available, construction work can start without delay. The main points of the schemes will be summarised in next article.

Article 2. Outlines of the Project.

The main purposes of the regulation of the Huai River systems are for flood control and improvement of navigation and irrigation, while the development of water-power is a secondary one. Flood problem should be solved, before utilization of the water resource is possible. Here we should pay attention to the value of two lakes the Hungtze and Weishan, on the Huai River and Grand Canal respectively

The same lakes that have roused continuous conflicts between the people living on the opposite shores should also be duly considered in this connection. Any one is concerned with the problems of flood detention, navigation, irrigation and water-power, should at first think of the possible reservoir sites. Only through existence of them their solution becomes possible. Hence the key of solving the problem of Huai River regulation lies in the well utilization of these natural reservoirs.

The benefit of water in irrigation land to increase its productive power is well-known to all, another important factor in its power of production is often neglect, that is transportation. In the Huai region, the only thorough fare existed is the Tientsinpukow Railroad, which is naturally insufficient in serving such a vast area and population. The under-development of industry and commerce, the poverty of the general public, and the bandit disturbance are all due to the sad conditions of communication. It is only through the regulation of the Huai River system that all these reverse conditions can be mended. With the supply of cheap water power and low rate of water freight, which is counted to be only from one-fifth to one-tenth of that of railroad transportation, industry can be flourished. The projects contained in this report includ the flood control, the improvement of navigation and irrigation, each being dealt with somewhat in detail, while water power being left for further investigation. The main items are summarized as follows:-

1.) It is to provide for the Huai River a principal flood channel through the San Ho, Kao-yu Lake, Shaopai Lake, Liochiakou River to the Yangtze Kiang. The flood discharge through this channel is regulated so that it will not make the water surface of the latter river higher than the H.H.W.L. of 1921. At its head, near Chiangpa, movable dams will be constructed as the regulator. As soon as the water level of the Yangtze increases to the H.W. stage as in 1921, part of the gates will be closed so as to limit the discharge down to 6,000 c.m.s. and as soon as the Yangtze River receeds, the discharge can be increased up to 9,000 c.m.s. which is the highest limit the regulator and flood channel are designed for. By this means, the discharge of the Huai to the Yangtze Kiang will be regulated at will and will not endanger the latter by discharging as much as possible, which is the condition existed at present. Hence the flood condition of the Yangtze will be reduced, too. The cost of construction for this channel is very low, since most part of it lies in the lakes and low land, and it requires only two dikes on both sides to create the needed channel. Land amount to more than 10,000,000 mou in the region of Kao Pao Lakes (Kao Yu and Pao Ying) can be reclaimed after the dikes are built.

2.) After the Chiangpa regulator is constructed, the water surface in the Huangtze Lake can be maintained at 13.60m. in the ordinary time, and not lower than 11.00m. when extremely drawing down for the same of maintaining navigation. The lake in this way can furnish enough water for irrigation use, with sufficient slope.

3.) The Hungtze Lake will be used as detention basin for flood water. Before a flood is set in, the lake will be emptied to the elevation 12.50m. If by that time the Yangtze Kiang is not at a danger stage and the Huai River flood is moderated, the inflow to the lake being less than 9,000 c.m.s., then the regulator will be open to discharge as much as possible. As soon as the inflow is increased to and over 9,000 c.m.s., then part of the gate will be shut down to limit the outflow to 9,000 c.m.s. while the excess quantity of inflow will be retained in the lake. Based on the standard flood peak of 15,000 c.m.s, the necessary time of retaining the inflow water is about 25 days with an amount varies from zero up to 6,000 c.m.s.. The lake surface will be increased to 15.60m. If the H.H.W. of the Huai River and the Yangtze Kiang meet together, then the discharge of the flood channel to the latter will be limited to 6,000 c.m.s. in the critical moment, and the lake surface will be likewise higher, that is 16.10m. This will be the rarest happening. and will not be met with oftener than once in 1,000 years. If another outlet to the sea is provided in the future for the Huai when fund is available, this condition will still be improved.

4.) It is necessary to dike the Huai River above the Huangtze Lake, and its principal tributaries, since with the flat topographic feature of those rivers, no other method than the dikes will be practical for controlling the flood water. The Huai river proper will be strongly diked from Hunghokow to Shuangkou, while the tributaries, such as Hung Ho, Yin Ho, Pei Ho, Shih Ho, Hsifei Ho, Chien Ho, Kwo Ho, Kwei Ho, To Ho, and part of Peifei Ho should also be diked. channel correction will be effected at such places as the points of confluence of the Huai with Yin Ho and Hsifei Ho. Several tributaries such as Chien Ho, Peifei Ho will be combined into the Kwo Ho before they join with the Huai River. Several cutoffs are also necessary at Lotaitze, Sanhochien, Cheochiachih and Fengtai city. Near Shuangkou, the Huai River will be conducted to the Hungtze Lake at Lihowa through a short cut in the hills. Several plac s, where the cross-section of the Huai River is not broad enough will be widened, such as Hunghokow, Fengtaitze, Fengtai, Pengpu, Leihokow, Anhuaichi, etc. The bridge of T.P.R.R. at Pengpu will be provided with additional openings.

5.) Many lakes and swamps are existed near the banks of the Middle Huai River and its tributaries. They can be used to retain temporarily the excessive rainfall. Those places where no drainage work by gravity is possible, are to be drainedby means of pumping. Either wind power or other source of energy can be used for pumping.

6.) It is to provide seven locks in the Grand Canal from its junction with the Yangtzekiang up to that with the Yellow River. The locks in the order will be Shaopai, Huaiyin, Liulauchien, Yutingchai, Teshenchai, Chunchiakow and Chiangchiakou on the Yellow River. The locks for immediate use will be designed for ships of 900 tons, but spaces will be reserved for future extention for ships up to 2,000 tons. The shallow places between each pair of locks will be dredged, and some repair work is necessary for the dikes. The portion of the Canal below Shaopai lock will be open, and connected with the Yangtze Kiang by ways of Yangchow and Sankiangying. The lock at Huaiyin will be used for the inter-communication of ships from four directions, that is the Changfu Ho, the Salt Canal and both directions of the Grand Canal. The old Chai's at Huaiyin will be abandoned.

7.) From the Changfu Ho up to the middle portion of the Huai River, no more lock is necessary. A new channel to connect with the Salt Canal for the Changfu Ho will be constructed near Huaiyin. In the Salt Canal, two locks, one at Tsaikungtu, and another at Hsinpu will be provided, while in the Kwan Ho, one lock is also necessary. They are all to be designed to accommodate ships of 900 tons, and spaces reserved for future extension. The shallow places will be dredged.

8.) In the eastern bank of the Grand Canal at Liulauchien, a spillway will be provided to discharge the flood water of the Sze River into the Yi River. At the sides of locks above Liulauchien, movable dams will be attached for passing flood water. The Wishan Lake will be used to retard the flood water coming from its upstream.

9.) The Wishan Lake will be used as a reservoir. Its W.L. will be maintained between 35.1 and 30.6m. In this way the maximum outflow from the lake will be limited to 1,000 c.m.s.. The storage will be used for navigation and irrigation.

10.) The closing dam at Lukowpa on the Yi River will be rebuilt into a movable structure so as to confine the flood water of the Yi River running southward across the Loma Lake, and at the sametime, part of the water can be diverted into the Grand Canal incase of need. Other branches are to be closed, so the Yi River can be separated with the Grand Canal. It runs down to Sanchatu where it joins with the Sze Ho coming form Liulauchien on the Grand Canal, and thence to Kwan Ho by way of the Peiliutang Ho.

11.) The Shu Ho will be conducted in the original channel to Shuyang, and entering the sea at Linhungkow, by way of Chienshu Ho, and Rose River. It is to be separated with the Yi River. The sites for detention basins on the Yi and Shu for retarding the flood peak are to be investigated further on.

12.) A small lock is to be built at the side of the Chiangpa movable dam for the convenience of small junks running up and down the San Ho.

13.) The Hsun Ho will be used as a canal for conducting water in the Hungtze Lake to the Grand Canal, Ching Ho, Sheyang Hu and Chuangchang Ho at Kaoliangchien. A lock will be put on the Ming Dike at Kaoliangchien, another be put at the junction of the Grand Canal and Ching Ho. The irrigation water required by the land on both sides of the Grand Canal and up to the Fankung Dike will be supplied by this canal. The flow at Ching Ho will be diverted into three directions, north to Huaiyin, south to Shaopai, and east to the Chuang-chang Ho. The total area irrigated will be 15,000,000 mou. This canal will also be used for the junks in the Grand Canal to go through the lake to the upstream of the Huai River.

14.) A new canal will be built from a place at the upstream side of Tsaikung Lock on the Salt Canal southward to join the Chuang-chang Ho, so as to supply irrigation water to the land at the east of the Fankung Dike, and also for navigation. The sites of locks in the Chuangchang Ho and Hsinyangchiang will besettled after detail survey is made.

15.) A lock and movable dam will be provided on the Huai River between Fushanchia and Huanghokow for extending the navigation route far upstream.

16.) A sea harbour will be placed at the mouth of the Kwan Ho as the terminal for inland and outbound ships. It is pending for further investigation.

17.) A water-power station of some 50,000 H.P. capacity will be built near the Chiangpa movable dam. Fushanhsia on the Huai River and Vishan Hu on the Grand Canal have also possibilities for developing water power, though at a smaller scale. Further investigation is under way.

The order of carrying on all the works stated above will be discussed in next section.

Article 3. Construction Program and Costs.

The order of carrying out all the projects of flood control, irrigation and navigation in the valleys of the Huai River system is warthy for consideration. The construction program should be so arranged that it will be consistent with the present financial condition, the importance of work and the benefit resulted. Take the whole into consideration, the project of flood control must be executed befor the irrigation and navigation works, because the harmful elements should be removed at the very start. As to the individual projects, the regulation of rivers should be started from downstream side up so as to serve the purpose of a general relief to the whole river. The canalization of waterways must be started in those rivers where the improvement for water transportation is urgently needed. The irrigation water must first be applied to the most important agricultural district, and then to the newly reclaimed area in turn. With these points in view, the construction program and the yearly budget are set forth as follows:-

Table I. Construction Program and Budget for Project of Primary Importance.
The First Stage of Development.
1931 – 1936

Division of Works	Year					
	1st. year	2nd. year	3rd. year	4th. year	5th. year	Total Cost
Flood Control Projects	8,218,200	8,218,200	7,718,200	7,818,200	600,000	$32,572,800
(1) Construction of the Chiangpa Movable dams and lock	1,000,000	1,000,000				2,000,000
(2) Construction of the Flood Channel through the Kao-Pao Lakes	7,218,200	7,218,200	7,218,200	7,218,200		28,872,800
(3) Reparation of the dikes around the Hungtze lake and Providing drainage outlets				600,000	600,000	1,200,000
(4) Construction of 3 movable dams in the Middle Grand Canal			500,000			500,000
Irrigation Projects	150,000	750,000	3,050,000	2,300,000	3,350,000	9,600,000
(1) Installation of New head gate in the dikes of Inner Grand Canal for the irrigation laterals	100,000					100,000
(2) Reconstruction of the head work at the west end of the Tungyang Canal	50,000					50,000
(3) Construction of the irrigation Main Canal between the Hungtze Lake and Chinghochai		750,000	750,000			1,500,000
(4) Reclamation of the Kao-Pao Lakes			2,300,000	2,300,000		4,600,000
(5) Construction of the irrig. Main Canal between the Salt Canal and Chuangchang Ho					1,110,000	1,110,000
(6) Construction of the irrig. Main Canal between Chinghochai and the Chuangchang Ho					2,240,000	2,240,000
Navigation Projects	1,925,200	1,630,900	1,651,600	2,000,000	16000	7,367,700
(1) Construction of Huai Yin and Shaopai, locks	750,000					750,000
(2) Improvement of the Channel from Liulauchien to Sankiang-ying and Huaiyuan to Tsaikungtu	875,200	800,000			160,000	1,835,200
(3) Construction of 3 locks at Tsaikungtu, Hsinpu and Lung-kou	300,000	600,000				900,000
(4) Construction of the strawdam and movable dams at Lung-Kou		200,000				200,000
(5) Improvement of the Channel between Tsaikungtu and Hsinpu		30,900				30,900
(6) Construction of 3 locks at Liulauchien, Hotingchai and Teshengchai			1,100,000			1,100,000
(7) Improvement of the Channel from Chunchiakow to Liulauchien, and reconstruction of the railway bridges and [illegible]			551,600	2,000,000		2,551,600
Total for each year	10,293,400	10,599,100	12,419,800	12,118,200	4,110,000	$[illegible]

Table 2. Construction Program and Estimates for Projects of Secondary Importance.

Second and Third Stages of Development

To be Executed after the Completion of the Works shown in Table 1.

Period	Items	Division of Works	Cost
First Period	Flood Control Projects	(1) Regulation of the Yi Ho	$ 9,596,400
		(2) Regulation of the Sze Ho	372,200
		(3) Regulation of the Shu Ho	7,759,200
		(4) Regulation of the Upper Huai River	70,000,000
	Irrigation Projects	(1) Deepening the channel of the Inner Grand Canal between Fan-shui and Kao-yu, and raising the dikes of the same between Huai-an and Fan-shui	757,600
		(2) Construction of the locks of the outlets of the Chuangchang Ho to the sea and the Tungyang Canal to the Yangtze River	to be estimated
		(3) Construction of the locks and canals along the Middle Grand Canal and Pelao Ho	,,
	Navigation Projects	(1) Canalization of the Southern Grand Canal in Shantung	,,
		(2) Construction of the lock and movable dam at Huai-yuan for the canalization of the upper Huai River	,,
		(3) Construction of the jetties at Linhungkow and Kwanhokow	,,
Second Period	Flood Control Projects	(1) Regulation of the tributaries of the Upper Huai River	,,
		(2) Regulation of the upper portions of the Southern Shantung rivers	,,
	Irrigation Projects	(1) Irrigation and Drainage along the Southern Shantung rivers	,,
		(2) Irrigation and Drainage along the Upper Huai River	,,
	Navigation Projects	(1) Construction of the locks for intercommunication of the Salt Canal, Chuangchang Ho, and Inner Grand Canal	,,
		(2) Deepening all the channels and adding new navigable locks for ships up to 2,000 tons	,,
	Water Power development	(1) Construction of the power plant at Chiangpa, on the Hungtze Lake	,,
		(2) Construction of the power plant at the outlet of the Wishan Lake	,,

The projects contained in Table 2. will be further investigated in order to reduce their costs to a minimum.

After the completion of the primary works, the land which is relieved from floods and well irrigated will amount to 20,000,000 mou (one mou is equal to 6.67 are or 0.132 acre). If an annual water tax of $0.10 per mou be imposed, we can have $2,000,000 per year. The navigable distance throughout the year will be 913 km. If it is assumed that the yearly transportation for the first few years be 2,500,000,000 ton-km., and a tax of $0.003 per ton-km. be imposed, we can have a total annual income of $7,500,000. The reclaimed lands, in the Lao Pao Lakes will be 1,000,000 mou, while the public land within the dikes of the Old Yellow River will be 950,000 mou. After improvement of the Huai River, since no flood water would pass through the Old Yellow River bed, it can be offered for cultivation. Suppose the price of new land in the lakes to be $40 per mou, and that in the Old Yellow River bed to be $10 per mou, the total price of land will worth more than $50,000,000. With these sums of money, the secondary works can be carried out without any financial trouble.

Article 4. Benefits

1.) Land Protected from flood:

In the Huai River valley above the Hungtze Lake	20,000,000 mou
On both sides of the Inner Grand Canal	18,000,000 mou
In the drainage areas of the Yi, Sze and Shu Rivers	12,000,000 mou
Total...............	50,000,000 mou

2.) Land to be reclaimed:

Between Shuyi and Wuho on the Huai River	500,000 mou
In the Old Yellow River bed	950,000 mou
In the Lap-pao Lakes	1,000,000 mou
Total......................	2,450,000 mou

At the average price of $25/mou, it will worth approx. $60,000,000.

3.) Land to be irrigated with sufficient water:

Around the Lao-Pao Lakes	2,250,000,000 mou
Between the Inner Grand Canal and Fankung Dyke	11,740,000 mou
Along the Tung-yang Canal	2,500,000 mou
Along the sea coast at the east of Fankung Dyke	5,000,000 mou
At the South of the Wishan Lake	20,000,000 mou
Total................	41,490,000 mou

Annual tax upon lands @ $0.1/mou, it is $4,1490,000 per year.

4.) Total navigable distance will be 913km. Assume yearly transportation to be 2,500,000,000 ton-km. within the first few years, and a tax upon merchandise to be $0.003/ton-km., it will give a total sum of $7,500,000 per year, charges of lockage and wharfage being not included.

Chapter II. Projects of Flood Control

Article 1. Flood Magnitude and Frequency of the Huai River.

The Flood Magnitude

The Huai River takes its rise in the Tungpai mountains in the Province of Honan, collects the waters of its many tributaries, as the Hung, Ju, Huan, Shin, Pei, Ying, Fei, Kwo, Kwei and Tse of the Provinces of Honan and Anhwei and empties to the east into the Hungtze Lake at Kwei-shan. After issuing from the lake, it divides into two courses, the San Ho and the Changfu Ho, and dissipates its water into the Yangtze Kiang and the sea through different channels. The total quantity of inflow of the Hungtze Lake therefore represents the total quantity drained by the Huai River. But owing to the difficulties of making stream gaging near the junction of the Huai River and the Lake, the principal gaging station has been established at Pengpu. From the authentic maps, the drainage area of the Huai River above the Hungtze Lake and Pengpu was found to be 166,110 and 124,610 sq. km. respectively. If the flood discharge is proportioned to the drainage area, then the discharge at Pengpu represents only 75% of the total. It is approximately correct to count for the flood discharge of each tributary by the rate of runoff per unit area based upon the data obtained at Pengpu gaging station, as the meteorological, geological, and topographical characteristics of those tributaries are much ~~the~~ same. By this means, the maximum rates of discharge for successive years are computed as follows:-

Table III. Max. Discharges of the Huai River

Year	c.m.s.	Year	c.m.s.
1915	2,100	1920	1,600
1916	12,900	1921	6,200*
1917	3,300	1922	1,570
1918	2,400	1923	4,250
1919	3,350	1924	3,900

*Part of the flood flow escapes through the dike-breaks above Pengpu in that year.

From the above table, we can see that in two years, the flood flow happens between 1,000 and 2,000 c.m.s.; another two years, between 2,000 and 3,000 c.m.s.; three years, between 3,000 and 4,000 c.m.s.; one year between 4,000 and 5,000 c.m.s.; and two years above 5,000 c.m.s.. Among them, the flood of 1916 is the maximum. But as part of the floodflow was escaped through the dike-breaks in 1921, the record of that year is not reliable. As to the gage readings at Pengpu it reached 19.84m. in 1921, and 19.825m. in 1916, that of 1921 was actually higher. In comparing the maximum discharges of the San Ho, the main outlet of the Hungtze Lake, we find 14,600 c.m.s. in 1921 and 8,400 c.m.s. in 1916, and it again gave a higher figure in 1921. It is not disputed that the floods of 1916 and 1921 both show a high record. The maximum discharge of 1916 is 12,900 c.m.s. as stated above, while that of 1921 is to be found out by other means.

The total discharge of the Huai River can be reckoned as the sum of discharges of the San Ho and Changfu Ho, plus or minus the depletion or storage of the Huangtze Lake at any time. The records for discharge of the above two rivers in 1921 are available, while the storage or depletion of the lake for that year can only be approximately known from the gage readings at Chiangpa. After removing the irregularities on the resulted curve, the flood peak of that year is obtained as shown in Figure 2. (The storage capacity curve of the Hungtze Lake is shown in Figure 1.)

From this figure, we can see that the maximum inflow of the Hungtze Lake, or the discharge of the Huai River for that Year, was 15,000 c.m.s.. It exceeded that of 1916 by 2,100 c.m.s.. Hence it can be assumed as the highest magnitude of flood discharge for the Huai River. (This value, in the opinion of Prof. Otto Franzius, is rather too high, but for safety it is still to be adopted.)

If channel improvement be used as the sole means of flood control the highest flood peak of the river is the important basis for designing. But when retarding or storage reservoir be also used, then the duration of different rates of the flood discharge should also be taken into consideration. As in the above figure (Fig. 2) the discharge above 10,000 c.m.s. lasted about 30 days; above 12,000 c.m.s. 28 days; above 14,000 c.m.s. 18 days. It is quite different from another flood peak with the same quantities of discharges but with one half of their duration, since the storage required for above any quantity of discharge will be only one half of the former one. The required capacity of storage reservoir will becorrespondingly reduced.

The simplest way to show the magnitude and duration of different stage of flood dis-charge at the same time is by means of flood hydrograph, as shown in Fig. 2. in which the ordinates represent the quantity of discharge, while the abscissa, the corresponding time of occurrence. This kind of hydrograph, while constructed directly from field data, will represent actually the condition of flood flow, otherwise, it will be only an approximation. In the opinion of Prof. Franzius, this constructed hydrograph of 1921 will not be a normal case, and would hardly be taken place ever since according to his experience. His reasoning is that due to the dike-breaks, ances the flood flow was not in the ordinary form, therefore the derivation of such a curve with the ordinary method will not be correct. Also the computation of depletion andstorage of the Hu-ngtze Lake was based only upon a single gage at Chiangpa it is likely in error in considering the bigness of such a lake which is subject to winds and seiches. Hence the resulted hydrograph, when adopted, will be safe enough for flood of any magnitude, but will require too big an engineering work and expense which are really unnecessary.

The hydrograph at Pengpu in 1921, though it was modified bythe result of dike-breaks, still represents the actual condition of stream flow, except that the duration or time scale of the curve is somewhat lengthened. This is because the flow running out from the dike-breaks is usually slower than that in the river channel, and lags behind the flood peaks. This condition is best represented in Fig. 3.

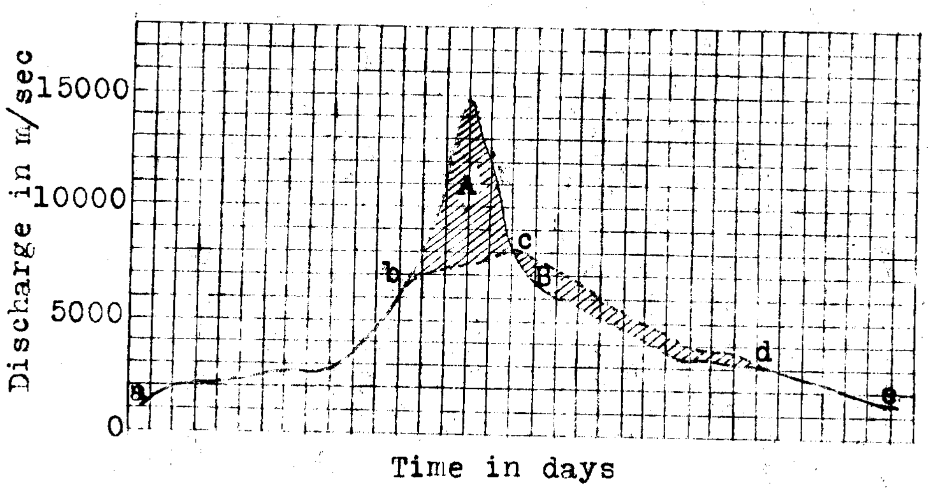

Fig. 3

The full line represents the hydrograph when the dike were not broken, and the dotted line, the same hydrograph resulted by the dike-breaks. The quantity of water represented by shaded portion A in the figure must be larger than that of B, for a part of it must have lost due to evaporation, percolation, or escaping into other rivers, before coming back to the original channel. For safety, when we assume the total losses numerated above to be one-half of the quantity of water escaped through dike-breaks, and also the highest rate of flood flow to be 15,000, we can construct the probable hydrograph of the Huai River for 1931 without dike-breaks by making the area A equal to twice B. The bounded line around A should be irregular instead of a smooth one, but owing to lack of record, a straight bounded line is used. A flood peak with straight bounded line is of course one of the worst. With this method the standard flood peak of the Huai River, as shown in Fig. 4, is constructed.

Frequency of Floods

It is evident that the average flood to be expected every year is exceeded by floods of less frequency that may occur at intervals of 5 and 10 years and that these will be considerably exceeded by greater floods which may occur at intervals of from 20 to 50 years, and that still greater flood will be expected even in thousand years. In order to predicate the frequency of floods of any stream, it is a matter of certainty that the longer the records, the more accurate the predication. But within the drainage area of the Huai River system, only a few gaging stations with records of one half a decade are available. It is far from being sufficient. Yet the frequency of a flood like that of 1921 which is adopted as the standard maximum flood for all designs of flood control works must be investigated by all means before going on further.

As flood originates in excessive precipitation, its amount and distribution are of primary importance. If when the rain-storm cover the whole area of river valley, and the duration of storm is just as long as the time required by the remotest rain drop reaching the gaging station, and also when the ratio of run-off to rainfall is a maximum, (that is when the evaporation, percolation, natural storage in the lakes and ponds, etc. are reduced to minimum) then the maximum quantity of flood peak is originated. Hence if the frequency of rain-storm can be known, the frequency of flood can be approximately known too. It is unfortunate that the rainfall records within the valleys of the Huai River are as short and incomplete as the discharge records, so they cannot be used for our purpose. But on the other hand we can obtain rainfall records lasting more than 40 years of the places in the neighboring valley of the Yangtze Kiang as kept by the Ze-Ka-Wei Observatory, Shanghai. The adjacent valley of the Yangtze Kiang has much the same meteorological conditions as that of the Huai River. Besides, when the typhoons, which is always accompanied with excessive rainfall, as occurred in the months of July and August, strikes across the lower Yangtze valley, it will also hit the Huai River basin. Hence the great rain-storm that occurred in the Yangtze Valley would also have occurred in the Huai River Valley. By the rainfall data of Ze-Ka-Wei Observatory at Chinkiang, Wuhu, Kiukiang, Hankow, and Ichang, all being lasted from 1880 to 1924, more than 40 years, the frequencies of maximum monthly and maximum daily precipitation are computed and plotted in Fig. 5. By assuming that five days be needed for the remotest rain drop to reach the Hungtze Lake, and also the ratio of run-off to rainfall during the ordinary flood period to be 20%, and during extraordinary one, 25%, the frequencies of floods can be determined with the aid of values obtained from the curve of maximum daily precipitation in Fig. 5, as follow:

Table IV. The Frequencies of Floods for the Huai River.

Based on rain-storm records.

Frequency	Max. one day precipitation	Averg. 5day precipitation on whole area	Mean daily precipitation	Ratio of Run-off to Rainfall	Run-off per 24 hrs.	Flood discharge c.m.s.
Once in 10yrs.	150 mm	172 mm	34.4 mm	20%	6.88mm	10,000
Once in 25yrs.	200	187.5	37.6	20%	7.52	11,000
Once in 50yrs.	245	198	39.6	25%	9.90	14,400
Once in 100yrs.	300	214.5	43.0	25%	10.75	15,500

Although the values in the above table are indirectly computed, but they offer a safe basis of comparison since all the steps of computation are very conservative. It is no doubt that the flood of 1921 will not occur more often than once in 100 years.

Mr. Weston E. Fuller has tabulated the ratios of different maximum flood flow of various streams to their average annual flood in the order of magnitude, and obtained the relation between floods to be expected in a series of years and the average yearly flood in the formula:

$$Q = Q_{av}(1+0.8 \log T)$$

Where

Q = maximum (24 hours average) flood in c.m.s.

Q_{av} = average yearly flood in c.m.s.

T = number of years in which the maximum flood is likely to occur

From Table III. (P.17) of the maximum yearly flood discharges of the Huai River, we see that the flood of 1923, 4250 c.m.s. is the third largest one besides those of 1916 and 1921. For safety, we substitute this value into the above formula as the average yearly flood, the following table is resulted:

Table V. Frequencies of Floods of the Huai River.

Based on Fuller's formula.

Frequency (once in years)	10	25	150	100	500
Flood discharge c.m.s.	8,100	9,530	10,500	11,700	14,200

The values of flood discharge are the average in 24 hours, while for the maximum flood discharge they may be increased by 10 to 20%.

The results obtained are similar but a little smaller than those given in Table 4. Anyhow the flood as that in 1921 must have a frequency of more than once in 100 years. Even the greater floods may be expected in the future, the rate of increasing must be very small.

Further more, itcan be proved by the historical records. In the 1921, inundation covered an area of 11,740 sq. km., to a depth of 1 to 4 meters, including the following cities:Houchiu, Yingshang, Fengtai, Shouhsien, Huaiyuan,Hushsien, Lingpi, Wuho, Szehsien and Shuyi. From Mr. Wu Tung-Chu's "Table of Annual Events of the Huai River System", we find that there were three great floods which were comparable to that in 1921 during the last 300 years: One of them occurred in 1649, and covered the districts Sihsien, Yingchow, Houchiu, Wuho and Szechow with a depth of more than 3 meters; another one occurred in 1741, and covered the districts Yingchow, Taiho, Yingshang, Houchiu, Pochow, Mengchen, Hsuhsien, Lingpi, Wuho, Szechow and Shuyi; still another one occurred in 1879, and covered the districts Yungchen, Hsuhsien, Szechow, Fengyang, Wuho and Shuyi. Besides those floods, the usual inundation only covered from 3 to 4 districts and certainly not to be compared with that in 1921. Even for the above said floods, the inundation areas were not so broad as that in 1921. Therefore it can be concluded that the frequency of the 1921 flood, even it may happen, must be more than once in 100 years. From above discussions, it is doubtless with great safety to adopt the 1921 flood as the standard basis for designing the regulation works of the Huai River.

Article 2?. Regulation of the Lower Huai River.

The Hungtze Lake, being a natural detention reservoir receives all the flood water of the Huai River which drains most part of the provinces of Honan and Anhwei. After issuing from the lake, the flood water runs through the Changfu Ho and San Ho and finds its way either into the Yangtze River or directly to the sea by passing through the flood escapes built in the eastern dike of the Grand Canal. The way leading the flood water from the Hungtze Lake to the Yangtze River passes through the San Ho and Kao- Pao Lakes and the flood escapes near Liuchai thence discharging into the Yangtze River at Sankiangying. It is the principal outlet of the Huai River. Owing to the high stage of the Yangtze River, and the insufficient capacity of the outlet the discharge of the floodwater of the Huai is usually limited in quantity and in consequence the outflow of the lake is always much less than the inflow. As to the channels leading to the sea from the so-called five flood escapes in the eastern bank of the Inner Grand Canal, they are usually too small in capacity that no great amount of flood water can ever be expected to discharge through them. Moreover, since the land level at the east of the Grand Canal is very low, so even it is possible to open these escapes in time in order to protect the valuable land up-stream or west of the Grand Canal, severe damages will surely be resulted. According to the past experience, whenever there is an extraordinary flood, the people on both sides of the Grand Canal will struggle hard for decision whether the flood escapes are going to be taken away or not. In consequence it is usually too late for the urgently needed peotection. Enormous quantity of flood water must have already accumulated in the Huangtze and KaopPao Lakes so that the regions adjacent to the lakes and the upper Huai River are almost always subject to inundation. At the last moment, when the escapes are finally opened the inundation spreads out all over the country no matter where it is. Thus whenever a great flood happens, it makes no exception on both upstream and downstream lands in suffering flood losses. According to the actual measurement of 1921 flood, the total maximum discharge from the Hungtze Lake in the Changfu Ho and San Ho was 15,158 cubic meters per second and the maximum total discharge both leading to the Yangtze and directly to the sea was 13,700 cubic meters per second. The difference of the above two values gave a quantity of flood water 1,458 cubic meters per second to be reserved in the Kao-Pao Lakes. If the condition like that keeps on for a certain period, the water sufface of the lakes will increase higher and higher so as to make the land upstream and near the lakes suffering much in flood damage. In case the capacity of the lakes reaches its maximum limit for reserving flood water, overflowing over the eastern dike of the Grand Canal is then apt to happen. It will be more dangerous to the land east of the canal. Therefore with the present condition of the lakes and Grand Canal, even the flood escapes leading to the sea are removed at the proper time in case of flood as in the year 1931, it will give no appreciable benefit in relieving from flood. Furthermore by this way it is simply to transfer the harmful flood water from the upstream land to the region east of Grand Canal. This is certainly not a good and proper policy. Now we meet with the difficulties that on one hand the present passages leading to the Yangtze can not carry an enormous quantity of the flood water of the Huai and on the other hand the capacity of the Hungtze and Kao-Pao Lakes has its limitation for reserving the flood water. A better solution of the problem for dissipating the flood water of the Huai must be made.

Many projects for the flood channels of the Huai River have been proposed by different authorities in the past decade. After having taken all the proposals into consideration and compared their relative economy by our engineering staff, it is concluded that the scheme of leading the flood water of the Huai to the Yangtze River is comparatively much more economical than any other channel leading directly to the sea. Also in the many schemes of leading the Huai directly to the sea, the way through the Changfu Ho, Yen Ho and Kwan Ho will cost least. Hence so far as flood control is concerned it is advisable to make the way leading to the Yangtze River as the pricipal outlet for the Huai River while a part of flood water may be discharged directly to the sea if preferred. The Hungtze Lake is a natural reservoir, the detention capacity of which must be fully utilized so that the construction cost of the outlet channel can be economized. During the dry seasons the discharge of the Huai and that in the Grand Canal are very small in quantity, hence a storage reservoir is also needed to meet the demand of irrigation water to the land on both sides of the Grand Canal. Owing to its elevated position, the Hungtze Lake can serve very well for the purpose.

After a thorough investigation of the question, and with due balancing of the floodcontrol, irrigation and navigation problems, three general principles are formulated as the basis for the solution, and they are as follows:

1.) The flood water of the Huai River is to be conducted into the Yangtze River within a safety limit so as to make no appreciable effect on the latter.

2.) The Hungtze Lake is to be utilized as a flood detention reservoir to retard the flood peak so as to minimize the cost of outlet channel.

3.) The Hungtze Lake is also to be used as a storage reservoir for the development of irrigation.

These will be fully discussed in the following pages.

Determination of the Amount of Flood Water to be Discharged into the Yangtze River.

According to the record of the former Kiang Huai Conservancy Board, the greatest amount of flood water of the Huai River discharged into the Yangtze River was 8,000 c.m.s., as occurred on September 19, 1921. On that date, the gage reading at Chinkiang was 22.90 ft. above W. H. Z. On August 21 of the same year, when the Yangtze River attained its highest stage of 24.50 ft. above W. H. Z. at Chinkiang, the amount of flood water of the Huai River received was about 6,000 c.m.s. Therefore the amount of flood water of the Huai River that can be discharged into the Yangtze River without appreciably affecting the latter during the flood season ought to be from 6,000 to 8,000 c.m.s.. Suppose there are no lakes serving as detention reservoir for the Huai River, then the safe amount of flood water flowing into the Yangtze River will be limited to 6,000 cubic per second. But in our case, with the Hungtze Lake as a equalizer, it is possible to cut down the amount of flow to 6,000 c.m.s. when the Yangtze River receeds. In this way, the Yangtze River stage can be maintained not over the

H. H. W. L. of 24.50 ft. above W. H. Z. The duration of H. W. is also not to be too much prolonged. It is the best solution of the problem that not only the flood of the Huai can be relieved, but also that of the Yangtze River is greatly lessened. In order to find out the maximum daily flow of the Huai which can be safely discharged into the Yangtze without doing any harm during the highest flood period of the latter, we have first of all, to investigate the relation of the water stage and its discharge, and also the present condition of flow of the Yangtze River fromNanking to Kiangyin.

According to "The Report on Hydrography of the Yangtze Estuary" by the Whangpoo Conservancy Board, the maximum discharge of the Yangtze at Nanking on July 19, 1915 was 72,000 c.m.s.. Since there are no great tributaries emptying into the Yangtze River between Nanking and Chinkiang, it will be approximately correct to assume that the same amount of discharge would have passed through Chinkiang the next day. The gage reading corresponding to this discharge was found to be 20.65 ft. at Chinkiang. But we have already stated that the H. H. W. L. at Chinkiang to be 24.50 ft. in 1921, the discharge corresponding to this stage must be much greater than that in the year 1915. Since we have no record of the actual measurement for this maximum discharge at Chinkiang, it can only be roughly estimated by the following method:

By Forchheimer's Formula,

$$Q = \frac{1}{n} A t^{.7} J^{.5}$$

$$Q_1 = \frac{1}{n} A_1 t_1^{0.7} J_1^{0.5}$$

In which, Q is the discharge in cubic meters per second; n, the Kutter's coefficient of roughness of the river; t, the average depth of water in meters; J, the slope of water surface of the river. Since the variation of the slope is very small with respect to the change of discharge, we can assume "J" to be constant. Then

$$\frac{Q}{Q_1} = \frac{\frac{1}{n} A t^{0.7} J^{0.5}}{\frac{1}{n} A_1 t_1^{0.7} J_1^{0.5}} = \frac{A t^{0.7}}{A_1 t_1^{0.7}}$$

$$Q = \frac{A}{A_1}\left(\frac{t}{t_1}\right)^{0.7} Q_1 = \left(\frac{A}{A_1}\right)^{1.7}\left(\frac{W_1}{W}\right)^{0.7} Q_1$$

where W being the average width of the river in meters. In case of a wide river as the Yangtze, the change of average width will be comparatively small during the rising river. Assuming $W = W_1$, we have

$$Q = \left(\frac{A}{A_1}\right)^{1.7} Q_1 \text{.............................(1)}$$

Now since we know the cross sectional area A_1 of the Yangtze River being 34,175 square meters corresponding to the discharge 72,000 cubic meters per second in the year 1915 at Chinkiang, and its cross sectional area A being 36,315 square meters corresponding to the highest stage on Aug. 21 in the year 1921, the maximum discharge on the latter date can be found by applying the above formula.

$$Q = \left(\frac{36,315}{34,175}\right)^{1.7} \times 72,000 = 79,800 \text{ c.m.s.}$$

At the time when the maximum flow of the Huai discharged into the Yangtze on Sept. 19, 1921, the cross sectional area of the Yangtze is found to be 35,413 square meters. In like manner we find the discharge of the Yangtze at Chinkiang on that date being 76,500 c.m.s. Based upon the above calculations, the relation of the water stage and the discharge at Chinkiang can be shown in the following table:

Table VI. The relation of Water Stage and its Discharge of the Yangtze River at Chinkiang

Date	W.L. (W.H.Z.)	Cross Sectional Area (sq.m.)	Discharge c.m.s.
Aug. 21, 1921	24.50ft.(7.47m)	36,315	79,800
Sept.19, 1921	22.90ft.(6.98m)	35,413	76,500
July 20, 1915	20.65ft.(6.29m)	34,175	72,000

From the above table, we can see that generally, every increase of 1,000 cubic meters per second in discharge, corresponds to a rise of 0.15m of the water surface elevation. This can be proved in another way.

By Forchheimer's formula

$$Q = \frac{1}{n} A t^{0.7} J^{0.5}$$

Since $\quad A = W \cdot t$

therefore $\quad Q = \frac{W}{n} t^{1.7} J^{0.5}$

or

$$t^{1.7} = \frac{n\,Q}{W \cdot J^{0.5}}$$

By differentiation, and treating n and W as constant,

$$dt = \frac{n}{1.7Wt^{0.7}}\left(\frac{J\,dQ - 0.5QdJ}{J^{1.5}}\right)$$

But $\frac{1}{n}t^{0.7}J^{0.5} = V$ (V being the mean velocity)

$$dt = \frac{JdQ - 0.5\,QdJ}{1.7WVJ}$$

When the discharge is increased by dQ, the value of the increment of the slope dJ is very small. For simplicity let dJ = 0, then

$$dt = \frac{dQ}{1.7WV} = \frac{AdQ}{1.7WQ} \quad \text{.................(2)}$$

We have already found that during the highest stage of the Yangtze River or 24.50 feet above W.H.Z. at Chinkiang, the corresponding maximum discharge was 79,800 cubic meters per second. Also the cross sectional area at that time was 36,315 square meters and its average width was 1,800 meters. Substituting these values in formula (2), the rise of W.L. for every increase of 1,000 cubic meters per second of discharge will be

$$dt = \frac{1{,}000 \times 36{,}315}{1.7 \times 1{,}800 \times 79{,}800} = 0.15 \text{ meter}$$

This checks with what we have found before.

After having dtermined the relation of the increment of water stage of the Yangtze River due to the additional discharge of the Huai River, we can next come to the problem of how much of the flood water of the Huai can safely be conducted to the Yangtze without serious effect on the flood condition of the latter. From the gage records of the Yangtze River at Chinkiang, we find that the flood condition of 1921 is the highest one on record. It can be used as the basis of our investigation. An hydrograph of the Yangtze River at Chinkiang for the months of August and September is first made as shown by the heavy line in Fig. 6. The corresponding daily discharges of the Huai River into the Yangtze River are obtained approximately from the record kept by the former Kiang Huai Conservancy Board, and are recorded at the lower portion of the hydrograph. The safe amount of discnarge of the Huai River into the Yangtze is then determeined day by day, and the probable hydrograph in the future is constructed by the already established relation, as shown by the light line in the same figure. The safe amount thus found varies from 6,000 c.m.s. during the highest flood crest of the Yangtze River, as in 1921, up-to 9,000 cm.s. when the flood of the Yangtze River is receeding. By this way, the future W.L. of the Yangtze River, after the Huai River is regulated, will never rise above the original H.H. W.L. Hence so far the Yangtze River is concerned, this method of regulation of the Huai River will not only be of no harm, but also beneficial. Since if the Huai River is left as it is, it will naturally endanger the Yangtze River by the uncontrolled flood water. Were the stage of the Yangtze River at its highest as Aug. 21, 1921, the discharge of 8,000 c/m.s. of the Huai into it would raise the Yangtze River 0.3m higher, the flood condition will be much more considerable. No body can assure that this worst condition will never happen if the Huai River is not regulated; but on the other hand, as soon as the Huai River is under control, this condition can be completely eliminated. That is why we say it is beneficial to the Yangtze River too.

The foregoing computations are based on the worst condition, that is, when both the maximum flood peaks of the Huai and Yangtze occurring at the same time. If they do not occur simultaneously or one of the flood peaks has less magnitude than that of 1921, the resulted hydrograph showing the variation of water surface elevation of the Yangtze after the admission of the Huai River will be still much lower. Therefore it is safe to take the amount of 9,000 cubic meters per second as the limiting value for sending the flood water of the Huai into the Yangtze River.

The Detention Capacity of the Hungtze Lake.

The maximum flood discharge of the Huai River is found to be 15,000 c.m.s., while the safe amount which can be emptied into the Yangtze River is only from 6,000 to 9,000 c.m.s. Their difference is great, and so it is necessary to find some method to provide for. As stated above, through past experience, we have already known that the flood condition of the Huai River, which has insufficient channel capacity at its lower course, has been greatly reduced by the presence of the Hungtze and Kao Pao Lakes. With the vast area and capacity of the Hungtze Lake, it can serve for our purpose as a detention reservoir to hold the excessive discharge of flood water that can not be sent down to the Yangtze River in a short time. This is considered as most economical arrangement in the scheme for the regulation of the Huai River.

Before taking up the method of how to operate the Hungtze Lake for flood control, let us briefly consider the principle of a detention reservoir in general. The flood flow of a river as shown by its hydrograph takes usually a sudden rise and fall in certain short period. It forms a flood peak. Its duration is usually not over a score of days. However, most of its flood damages, such as washing away dikes and homesteads, and overflowing over fields, are made in this short period.

Therefore one who is concerned with the regulation of a river must pay attention on this fact. Now if only the channel improvement is depended upon for flood control, it will be necessary to provide a channel of very big crossesection to cope with the highest flood discharge of the flow. For instance, the channel must have a capacity of 10,000 cubic meters per second if the highest value of the flood peak is 10,000 cubic meters per second, while the channel must be capable to discharge 20,000 cubic meters per second in case its maximum flood peak reaches such a high value, and so on, notwithstanding whether the duration of the flood peak lasting several weeks or few days or even only a few hours. In this way the cost of the regulation work must be very expensive on account of the tremendous quantity of earthwork. If, on the other hand, reservoirs are available for the purpose of detention, the case will be changed. Once the flood flow is above a certain limit of the channel capacity, a portion of it can be temporarily reserved in the reservoir and gradually discharged at future time when the flood getting lower down. In this manner, although the inflow may vary to a great extent or attain to its highest peak, the discharge of the outlet channel will nevertheless be much smaller than the maximum value. This will render great economy in the expenditure for improvement of the outlet channel. Hence whenever there is a reservoir site which can be economically developed, one does not hesitate to use it for the regulation of a river. The Hungtze Lake is a good example for this case.

The maximum discharge of the Huai is 15,000 cubic meters per second, of which only 6,000 cubic meters per second can be discharged into the Yangtze when the latter is in its highest stage. If the Hungtze Lake is not existed, it will be further necessary to provide a large channel leading to the sea for the excessive capacity of 9,000 cubic meters per second. This will cost roughly not less than two hundred million dollars. On the other hand, if we use the Hungtze Lake as a detention reservoir not only the outflew into Yangtze can be regulated consistent with the water stages of the latter, but also the surplus water which cannot be discharged in the same time can be temporarily stored in the lake. Even another channel leading water to the sea is preferred its expenditure would be reduced on account of the detention ability of the Hungtze Lake.

The operation of the Hungtze Lake as a detention reservoir will be like this. Before the flood season, the lake surface will be lowered down from its ordinary stage (see Chapter on irrigation) to 12.5m suppose a flood like that in 1921 is set in, the regulator at Chiangpa will be open to discharge as much as the stage of the Yangtze River is not endangered. For the sake of reducing the cost of construction of the regulator and the flood channel, they are designed to discharge and carry the maximum flow of 9,000 until the elevation of the W.L. in the lake becomes 13.50m. Hence during the first stage of operation, the discharge through the regulator is less than 9,000 as fully illustrated in Fig. 7a and 7b. As soon as the flood inflow to the lake exceeds its outflow, the lake surface will raise, and its outflow is correspondingly increased due to the increasing of head of water. In case of the worst condition of flood that the flood peaks of the Yangtze and the Huai Rivers meeting at the same time, the regulator should be partly closed so as to insure that it would not do any harm to the former, as shown in Fig. 7a. If the flood peak of the Yangtze does not meet with that of the Huai, the condition will be better as shown in Fig. 7b. In either case the maximum outflow will be limited to 9,000 c.m.s.. Through the computation of the effect of the W.L. in the lake by the step method for routing flood, the resulted hydrograph of the lake surface are shown in Figures 7a and 7b. The highest W.L. attained will be 16.10m and 15.65m in both cases respectively.

Suppose it is designed [illegible] to discharge another 1,000 cubic meters per second directly to the sea, the maximum allowable outflow of the Hungtze Lake is then 10,000 cubic meters per second. Treating in the same manner as before, the highest water level of the lake will be only 15.3 meters (see Fig. 8a, 8b). With the building of small levees surrounding the lake, then all the land above the level 14.5 meters can be protected from flood. Also the King Dike of the Hungtze Lake can be safely depended for protection. This is, of course, the best and safest measure for flood control. However the channel leading to the sea will involve a big quantity of earth excavation, that at least ten million dollars will be necessary. Besides, the maximum water level of the lake of 16.10 meters can only be occurred when both the maximum floods of the Huai and Yangtze occur at the same date; The probability of such an occurrence will be very rare. Even it happens, the duration of the high water stage is not very long. Hence it is not neccessary to care for any great loss due to inundation. In conclusion, the primary important step to be taken for regulation of the Huai is to provide a channel to the Yangtze. And levees surrounding the lake must be also repaired and added for additional safety, so as to make the land above 14.5 meters in elevation around the lake good for agricultural use. The work for the channel to the sea may be postponed to the future time when there is a better financial and social condition and also in pressed requirement for further development of that country.

The Course of the Flood Channel From the Hungtze Lake to the Yangtze River.

The present course of floodwater of the Huai River follows naturally the San Ho and the chain of lakes such as Kao-yu, Pao-ying, etc., and merges into the Grand Canal at Liu-chai. By passing through the flood escapes in the dikes of the Grand Canal, it follows the Tongchiakou, and Liochiakou, to join the Yangtze Kiang at Sankiangying. Let us first examine briefly the local conditions of the different sections of the course. The San Ho is the first section of this natural course, lying between the Hungtze and Kao-Pao Lakes. It has a narrow channel but of great depth at its upper portion from the Hungtze Lake to Sanhowei and a shallow channel but broad one at its lower portion from Sanhowei to Kao-Pao Lakes. Its channel is so irregular that it has a minimum breadth of three hundred meters only up to more than two kilometers in some other places. The channel capacity of the San Ho is comparatively high; it discharged 8,400 c.m.s. in 1916 when the lake W.L. was at 13.70m, and 14,600 c.m.s. in 1921, when the lake was at 15.77m. Due to its high velocity, the loss of head in the short distance was considerable. But in our case, we are going to let this sectionof the course to convey 9,000 c.m.s. only when lake W.L. is at 13.50m. Very little enlargement of the river bed is necessary. The next section is in the chain of lakes. Because the flood escapes in the eastern dike of the Grand Canal can not be put into operation on the right time, those lakes have been called for reserving a part of the flood flow. On the other hand, even those lakes are separated from the Grand Canal by the western dike, yet they are actually not by the existence of many breaks in the dike. Once the W.L. in the lake rises, that of the Grand Canal follows too. This condition calls for more flood escapes leading water to the sea for the safeguard of the eastern dikes of the Grand Canal. In the present scheme, however, since part of the flood flow of the Huai River can be detained in the Hungtse Lake, and else can be sent down to the Yangtze, these lakes and flood escapes are no more needed. Only two parallel dikes are to be built in the chain of lakes to serve as a definite channel for flood water, while the remaining area can be used for reclamation. By utilizing the depth of the lake and the cheapness of the bottom land, a deep and wide channel can be economically constructed. At the same time, by selecting the shortest and deepest route, not only construction cost can be greatly reduced, but also it is possible to save for the loss of head. The proposed channel is to meet with the Grand Canal at the downstream side of the proposal Shaopai Lock (See Chapter on Navigation Projects), it does not interfere with the navigation of the Grand Canal during the flood season. The Tung Yang Canal will be separated from the flood channel by closing dams built in the original head bay at Liuchai and connected with the upper pool of the Shaopai Lock. New lock and sluice will be provided for at the head of the Tungyang Canal for navigation and irrigation. To the south of Liuchai the flood channel will be led through the five existed channels, namely Kingwan, Tungwan, Fenghwang, Sin Ho, Pihu and then combined into two main courses, Tongchiakou and Liochiakou and finally discharging into the Yangtze River at Sankiangying. The existed flood escapes in the five channels will be entirely taken away. When the gage reading at Liuchai was 8.41m in 1921, the discharge through the five channels was found to be 7,841 c.m.s.. In order to increase its capacity to 9,000 c.m.s., even with a lower stage, it will not involve too much earthwork. The annual cost for operating these flood escapes can also be saved forever. The proposed course of the flood channel is fully illustrated in Figures 9a and 9b.

<u>General Remarks on the Design of the Flood Channel</u>

1.) ALIGNMENT The general course of the flood way has been described in the last article. Since the cross-section of the San Ho adjacent to the Hungtze Lake is not sufficient to discharge the whole quantity of water without too much loss of head, a new channel of 5.8 kilometers long must be excavated to the north of Chiangpa and joining the San Ho near San Ho Wei.(See Fig. 9b.)

The flood flow from the Hungtze Lake will be regulated by means of two movable dams to be constructed in the San Ho and the new channel. The combined flow follows the original course of the San Ho till Paichiawan, east of Mingkouchen, where it is to be deviated southward to Taichiachien and then southeasterly to join the river Hsin Ho. Although the land travelled is generally high from Paichiachien to Hsin Ho, yet it is taken because it is the shortest way for the Huai getting to the Yangtze. At this place, for the sake of seeking a minimum sacrifice of the small villages and farm lands its course is made in a reversed curve. Yet it will make no obstruction to the flood discharge. Starting from this cut it runs in a southeastern direction through the Kao-yu Lake directly to the Tangchia Lake. It meets with another high land in the region between Tanchiachien and Huchuangwei where the channel is also located with several short turns in its way. After passing Huchuangwei, it runs through the Lanku to Shaopai Lake and thence to Liuchai where it joins with the five channels to the Ancient Canal, and combines into two main courses to the Yangtze River. The total length of the whole course is about 153 kilometers.

2.) DISCHARGE The channels at different sections along the course are designed for the maximum discharge of 9,000 c.m.s.. The two courses leading water from the Hungtze Lake are designed to pass 4,500 c.m.s. in each. From their junction to Liuchai, there is only one main channel, which is hence designed for 9,000 c.m.s.. From Liuchai to the Ancient Canal, the flow is again divided into five parallel channels. Its distribution is as follows:

the Kingwan Ho	1,500 c.m.s.
the Taiping Ho	2,500 c.m.s.
the Fenghwang Ho	2,000 c.m.s.
the Sin Ho	2,000 c.m.s.
the Inner Grand Canal	1,000 c.m.s.

The sum of the discharge in the above five canals is still 9,000 c.m.s.

From the Ancient Canal to Pakiangkow, the flow is divided into two passages. One is Montao Ho to discharge 1,500 c.m.s., and the other is Liochiakou to discharge 7,500 c.m.s.. Below Pakiangkow, it is designed to pass the total maximum discharge through Shatou Ho into the Yangtze. That the quantity discharged from Kuachowkow into the Yangtze being very small is not taken into consideration for safety.

3.) GRADIENT The entire course of the flood channel from the Hungtze Lake to the Yangtze River is about 153 kilometers. The water level just below the movable dam is at 13 meters when lake elevation is at 13.50 meters, while the H.H.W.L. of the Yangtze is 4.3 meters. The total available drop along the course is therefore found to be 8.7m. (See Fig. 10). Different drops in water level are assumed for different sections along the course. From the place just below the movable dam at Chiangpa to Paichiachien being 34.89 kilometers in length, its drop is 1.6 meters. From Paichiachien to Liuchai, the distance is 77.51 kilometers while its drop is assumed to be 3.9 meters. The section from Liuchai to Sankiangying being 40.27 kilometers long is designed with a drop of 3.2 meters. The variation of the slopes of the water surface for different sections is clearly shown in Fig. 10. In general, it is so arranged that in case the original channel is large enough to pass the flood, its natural slope of flow is taken; that when the channel must be excavated through high land, the drop in water level is assumed comparatively greater; and that when the channel passes through low land or lakes, it is then designed to consume a smaller drop. This will render the cost of excavation and dredging to be most economical.

4.) THE REGULATORS. The regulators to be constructed at Chiangpa are designed to pass 9,000 cubic meters per second when the lake elevation is at 13.5 meters. The floor of the movable dam is averaged at 8m. in elevation, and the drop of head in passing the dam is assumed to be 0.5 meter. By the following approximate estimation, the length of the clear opening of the movable dam must be 600 meters.

$$Q = 0.96L\,(H-h)\sqrt{2gh}$$

Q = 9,000 c.m.s.

H = 5.5 m.

h = 0.5 m.

L = 600 m.

Many types of movable dams such as stop logs, needles, Tainter gates and Stoney gates have been investigated and designed. But which one is the best to be adopted can only be decided after the actual test of the soil condition at the site of construction is made. So far as the cost is concerned, it will make no great difference in the choice of types. Approximately it will cost about three thousand dollars for every meter in length of the movable dam. Therefore the estimation for the movable dam is about $2,000,000.

5.) DIKES As for the standard section of the dike, the top width is assumed to be four meters and slopes on both sides, 1:3. This may subject to correction when model experiment on dikes is performed. The top of the dike must be 1.5 meters higher than the highest water level to be expected. In those places where excavation is necessary, the excavated material will be used for dike construction. In this case it needs only to pay the additional cost for tamping. In case no excavated material can be utilized, it is then necessary to pay for both hauling and tamping. For dikes along the flood channel from Chiangpa to Paichiachien the earthwork which needs to pay for both hauling and tamping amounts to 5,554,570 cubic meters, and that portion where excavated material is available and only tamping is requried is 2,024,500 cubic meters. From Paichiachien to Liuchai, the earthwork for dike construction which needs both hauling and tamping is about 17,020,500 cubic meters and that which needs tamping only is about 7,381,500 cubic meters. From Liuchai to the Ancient Canal due to high lands on both banks, only repairing work for the existing dikes is needed. Moreover excavated material is obtainable for dike construction everywhere along this section. The earthwork in this section, which needs tamping only is about 241,600 cubic meters. Below the Ancient Canal no excavation or dredging is to be performed. The earthwork for dikes from the Ancient Canal to Pakiangkow is

1,591,000 cubic meters and that from Pakiangkow to Sankiangying where the channel joins with the Yangtze is 1,143,000 cubic meters. As to the whole system of the flood channel, for dikes along both banks, the total earthwork which needs both hauling and tamping is approximately 25,309,070 cubic meters and that needs tamping only amounts to 9,647,600 cubic meters (See Fig. 10).

6.) EXCAVATION OR DREDGING Side slopes of 1:2 will be adopted for the excavated portion of the channel. For the new excavated channel at Chiangpa, the width of its highest water surface is 450 meters, and it has an average depth of 6.4 meters and a slope of water surface of 0.000098. The excavation needed for this canal is 10,225,000 cubic meters. From the Huntze Lake to Paichiachien along the San Ho the width of the channel at its maximum stage is from 520 to 1,400 meters; its average depth is from 5.9 to 8.22 meters and the slope of water surface is from 0.00005 to 0.000072. The earthwork of excavation for this section is 17,851,000 cubic meters. From Paichiachien to Liuchai the width of the channel at the highest water level is from 1,488 to 2,186 meters, its average depth from 4.5 to 6 meters, its slopes from 0.00003 to 0.00009 and the earthwork of excavation is 31,830,000 cubic meters. From Liuchai to the Ancient Canal there are five channels in parallel which will maintain their original width and will be deepened only by dredging. The average depth is from 5.7 to 12.2 meters, and the slope from 0.0000816 to 0.000094. The earthwork for dredging is 13,378,000 cubic meters. From the Ancient Canal to Sankiangying whence the flood water flows into the Yangtze, the original channel is enough for discharging the maximum flood. Hence no dredging work is needed for this last section. The computation is partly based on the topographical maps surveyed by the Huai-Yang-Hsu-Hai Topographic Surveying Board. Proper corrections will be made after the final survey is completed.

7.) ESTIMATES The approximate estimate for the cost of the flood channel of the Huai is summarized as follows:-

(a) Movable dams	$2,000,000
(b) Excavation and dredging	22,960,345
(c) Dike construction	4,295,592
(d) Land compensation	1,566,800
(e) Clearing the head bay above the movable dams	50,000
(f) Other miscellenious and administrative expense	3,000,000
Total..................	$33,872,737

Dike Construction Surrounding the Hungtze Lake.

Before another flood channel is provided to discharge the water into the sea, the land surrounding the Hungtze Lake will suffer the danger of inundation because of the high surface elevation maintained in the lake. For this reason, dike construction is then necessary. The old dike with stone facing on the southeastern shore of the lake known as "Ling Dike of the Hungtze ", if duly repaired, can be well used for protection of the land. Construction of new dikes will be known as "Ming Dike of the Hungtze", if duly repaired, can be well used for protection of the land. Construction of new dikes will be conducted in both directions to connect with the two extremities of the old dike. On the eastern side of the lake, it starts from Shunhochih to go around the Chentsewa along the contour line of elevation 14.5 meters and terminates at the high land west of the Anhowa. On the west of Sanhokow, in the same manner, a dike from Malangkang to Sankuanchih is to be constructed. The total length of the dike to be built amounts to 180 kilometers. As to the section of the dike, the width on the top will be 3 meters and slopes on both sides will be 1:3, and it will be built 1.5 meters higher than the highest water level. The earthwork amounts to 6,500,000 cubic meters, while its cost will be approximately $1,000,000. Sluice gates along the dike must be provided, when necessary, for the drainage of the land at different places adjacent to the lake. They will cost about $200,000.

Article 3. Regulation of the Upper and Middle Huai River and its tributaries.

Much of the flood damages on the upper and middle Huai River have been caused by the insufficient capacity of the river channel which is called upon to pass an enormous quantity of water collected by the many tributaries below San Ho Chien. Besides that, the narrow canyon-like gorges at Fengtai, Huaiyuan and Fushan play a great deal of obstruction for the discharge of flood water. Most of the tributaries are as a rule shallow and narrow that local overflow is a common occurrance. According to the topographic map published by the Anhwei Conservancy Board, the inundated area in 1916 was 8,000 sq.km., while in 1921, was 13,700 sq.km. The extensiveness of the flooded area is worthy of our notice.

Flood Flow

There is no actual record about the intensity of floods of the upper Huai River and its tributaries. Rough estimates can be made by referring to the broken records of former Kiang Huai Conservancy Board of the gaging stations, established at Hunghokow, Sanhochien, on the Huai River and also on the Shih Ho and Yin Ho. It is tabulated as follows:

River	Flood Flow in c.m.s.	Remarks
Huai River(Hunghokow)	3,000	Surveyed at July 11,1921
Huai River(Shanhochien)	3,310	" " " 13,1921
Hung Ho(Ju Ho included)	1,000	
Shih Ho(Kuan Ho included)	3,200	" " " 13,1921
Yin Ho	3,100	" " " 20,1921
Pei Ho	1,600	
Hsifei Ho	300	
Kwo Ho	1,250	
Chien Ho	210	
Peifei Ho	330	
Kwei Ho	600	
To Ho	250	
Tse Ho	350	
Shui Ho	1,400	

The above tabulated values are only the probable maximum discharges of the various tributaries, but not necessary occur in the same year, or even so, they must not be discharged to the main river simultaneously. Therefore it is obviously that the discharge of the Huai River at any point should be smaller than the sum of the max. discharges of all its tributaries above that point. The probable flood flows of the main Huai River below the mouth of any tributary are left to be determined.

It is assumed that the max. inflow of the Hungtze Lake, for safety, being 15,000 c.m.s., while the corresponding discharges of Shui Ho and others which are to be discharged directly to the Hungtze Lake being 1500 c.m.s.. Hence the maximum flood flow of the main Huai River just above the Hungtze Lake can be assumed as 13,500 c.m.s.. That above every tributary upward should be deducted a certain amount of discharge due to that tributary. From this, we estimate the maximum discharge of each section of the main Huai River as the following table:

Sections				Flood Flow in c.m.s.
Localities		Mouthes of tributaries		
From	To	From	To	
Kweishan	Fushan	Hungtze Lake	Tse Ho	13,500
Fushan	Wu Ho	Tse Ho	Kwei Ho	13,000
Wu Ho	Huaiyuan	Kwei Ho	Kwo Ho	12,000
Huaiyuan	Fengtai	Kwo Ho	Hsifei Ho	10,000
Fengtai	Chenyangkwan	Hsifei Ho	Pei Ho	9,500
Chenyangkwan	Shuikangchih	Pei Ho	Yin Ho	8,500
Shuikangchih	Sanhochien	Yin Ho	Shih Ho	6,000
Sanhochien	Hungkokow	Shih Ho	Hung Ho	4,500

The actual record in the year 1931 tells us that the flood flow of the Huai River at Sanhochien only reached 3,310 c.m.s., while at Lukow, a short distance below Chenyangkwan, it reached 6,000 c.m.s.

only. The reduction of overflow after regulation will increase the the flood flow of the main while the separation of the occurrances of the flood peaks of various tributaries will decrease it. Owing to the lack of complete records, the probable future flood is still uncertain. But at any rate the above tabulated values can safely be used since they are one-fifth to one-third greater than the recorded maxima..

Regulation of the Main River

The present main channel of the Huai River below Hunghokow can carry only one-half the amount of maximum discharge due to its contracted and small cross-sections and flat slope. The dikes, also, are so low and incomplete that no protection from overflowing can be offered by them. Thus inundation must happen as soon as there is a flood of considerable magnitude, and in 1921, it was seen that the flood channel became as wide as 15km. The cost of earthwork makes it impossible to excavate a large channel that will discharge all the amount of flood flow which may occur. The only way we can do is to construct two long levees along the course of the main channel. Prof. O. Franzius, has the same idea too. In some localities, nevertheless, channel improvement should also be executed in order to arrive at a satisfactory solution. Hence several sharp bends of the channel should be eliminated by cut-offs, and insufficient cross-sections should be enlarged by resorting to dredging. The distance between levees is to be kept as uniform as possible, sudden changes are to be avoided. The height of levees should be such that the sum of the construction cost and value of flooded area included within the levees is a minimum. upon the foregoing principles the regulation work of the main Huai River is designed and will be briefly described in the following Paragraphs.

Cut-offs are to be executed at Kotaitze, Sanhochien, Chiaochiachih and Fengtai with an aggregate length of 18 km. For keeping the current in equilibrium, the new cross-sectional areas along each cut-off should be as near the original ones as possible. The average value of these areas is computed to be 2,800 sq.m. approximately, making total earthwork of 50,000,000 cu. m. for the whole. At the following localities the channels are to be enlarged by excavation: from Hunghokow to Chiangpakaintze, from Paifangtaitze to Fengtaitze, from Fengtai cut-off to Yenwotze, from Lunghochih to Meihokow, from Anhuaichih to Chichih, and from Pouchiatu to Fushan. The sectional areas to be cut are from 500 to 2,500 sq. m. Total earthwork will be 90,000,000 cu.m. It may be concluded that the total quantity of excavation work of the main Huai River between Hunghokow and Fushan amounts to 140,000,000 cu.m. The cost of doing this will be about $30,000,000. Besides this, new openings must be added to the railway bridge at Pengpu since the water passage under that bridge seems too small.

A new channel is desired to be excavated from Fushan passing directly through the high land at the southeast of Shuangkou and the Lihowa, to the Hungtze Lake. A small steep-sloped channel will be cut through at the starting. By means of the strong current it will be enlarged naturally to the desired capacity. By that time the dikes should be constructed so that reclamation of surrounding lands can be carried out. It is advantageous both to flood control and navigation since the length of the channel will be shortened by about 60 km. In the new cut-off, which has a total length of 18 km., 15 km. will be marshy land and 3 km. will be high land. Let the base width of the artificial channel be 100 m., side slope 1:1, mean depth 10 meters, then the excavation along marshy land will be 11,500,000 cu.m., and that along high land will be 6,800,000 cu.m. The cost of excavation, including a narrow channel in the Lihowa, will be about $5,000,000. The possibility of this kind of work may be determined after the soil investigation of the high land southeast of Shuangkou is made.

The total length of the levee of the main Huai River, from Hunghokow to Shuangkou, will be 410 km. According to our consulting engineer, Prof. O. Franzius's study, the most economical type of levee will be 5 to 6 m. in height, and average 3.5 km. apart. From the cross-sections taken by the former Huai Huai Conservancy Board and the discharges at various sections as above computed, it is found that the required distance between levees at the portion from Shuangkou to Huaiyuan will be 4 km., that from Huaiyuan to Liutzekow, 3 km., upstream of Chenyangkwan, will be 5 km., that from Liutzekow to Sanhochien will be 2 km., and that from Sanhochien to Hunghokow will be3km. The height of levees will be between 4.5 m. to 6.5 m., only at certain place with very short distance the height reaches to 7m. The freeboard is taken as 1 m. and side slopes at both sides 1:3. The top width of levee is taken as 6 m. so as to serve as a public highway at the same time. Banquette is to be constructed at the place where the height of levee is more than 5m. The top of a banquette is 2m. below the top of the levee, and is 10m. wide. The total quantity of embankment amounts to 100,000,000 cu. m. and it costs about $18,000,000. The private land area occupied by the levees, the borrow-pits, and the berms between amounts to 164 sq. km., or 266,000 mou. At an average price of $40, per mou, it costs $10,640,000. Besides the above, the costs for sluices pumping stations, etc. should also be added in. The total cost of levee construction, therefore, will be $35,000,000.

The land area of the proposed flood channel is estimated at 2,000,000 mou. It is still able to be used for cultivation, as it s subjection to flood will not be oftener than before, except that if it does occur, the depth of water on it will be deeper. On the other hand, after the improvement is completed, the duration of inundation on the above mentioned land will be shorter for flood water of the Huai River can quickly be discharged. Hence the benefit and disadvantage are still balanced. It is only necessary to exempt the land tax or giving a small sum of money as compensation, without amounting to a big expenditure.

The valley of the main Huai River is usually flat, its steepest slope is not more than 1:50,000. With this value and the mean depth of water of the flood channel, we found that the W.L. elevation at Hunghokow will be 28m., at Fushan, will be 20m. Below Fushan down to the Huangtze Lake by way of the proposed 18 km. short cut at Shuangkou the available drop of head is 3.5m., enough to create sufficient velocity to help the formation of the channel by natural erosion. The flood W.L. above Fushan was thought rather too high, but on account of the great expenditure involved in the enlargement of channel by dredging, there could be no other althernative than what proposed. The H.W.L. will be lowered naturally year after year as the erosion of the channel bed progresses. The total cost of the whole project for the main Huai River is estimated at £70,000,000.

Regulation of the Tributaries

Differant methods of flood control should be applied to the tributaries of the Huai River of different characteristics. But for their lower courses, the backwater effect of the flood flows of the diked main river will be higher than their bottom lands, so the construction of levees is also necessary. For economical reasons the small tributaries should be combined with the larger one. Also if the tortuous channels of the tributaries be found near to the main river, they can be shortened by providing cut-offs to the main river. Besides these, hill-side terracing at their head waters and cut-off along the channels may be provided if found economical and effective.

The Pei Ho, Shih Ho and Kuan Ho are all of mountainous streams, so retarding basins may be built to control the flood. But owing to the lack of actual data, this is left for further investigation. If it is found necessary to provide levee system, then the required length of levees for the Shih Ho, from Sankochien to Shintukow, just above the mouth of the Kuan Ho, is about 70 km., that for the Kuan Ho, from the river mouth to Liushupang, is about 40 km., and that for the Pei Ho, from the river mouth to Siaolecchih, is about 95 km. Nine cut-offs will be required to eliminate the sharp bends of the Huang Ho below Sanchakow, the junction with the Ju Ho, at a total length of about 14 km. The required length of levees for the Hung Ho is about 140 km. A new channel will be excavated for shifting the river mouth of the Yin Ho from Chenyangkwan to Shuikangchih of a total lengths of about 6 km. The length of levees for the Yin Ho, from the new river mouth to Huiliuchih is about 70 km. The length of levees for the Hsifei Ho, Hei Ho and Chiang Ho, is about 70 km. New channels will be excavated for the Peifei Ho from Kaotzutze to Yinsiaochih and then combine with the Kwo Ho, same for the Chien Ho from Tsaolingchih to Shakouchih and then combine with the Kwo Ho, and also for the Kwo Ho, from Shakouchih to Changchuang downstream of Huaiyuan, and combine with the main Huai River. The levees for the above rivers, the Kwo Ho up to I-tsenchih, the Peifei Ho up to Hsiangchiaochih, and the Chien Ho up to Wanfuchih have a total length of about 90 km. The To Ho and Peito Ho will combine with the Kwei Ho at Wuhohsien and discharge into the Huai River. The lakes along their lower courses, like the Hsiangchien Hu, To Hu, etc., will be preserved as the storage reservoirs. Around the lakes, levees will be constructed and extended up to Chungyichih for the Kwei Ho to Tsingchungchih for the To Ho, and to Lochiaochih for the Peito Ho. The total length of levees of these three rivers will be about 300 km. The small streams at the northern part of Szehsien, Lingpi and Suihsien will be conducted to the Hungtze Lake by way of the Pien Ho and Shui Ho. The channel bed of the Shui Ho seems too high, hence dredging as well as levee construction are necessary. The total length of this river to be regulated is about 90 km. Other than these, the excavation and embankment of the various small streams will not be considered here for they would not involve large sum of expenditure. Drainage structures such as culverts and pumps, should also be provided for draining away rain water collected on the bank sides of the levees during the H.W. period of the Huai River. Numerous lakes and swamps should be preserved as valley storages and at the same time to reduce the cost of drainage structures. The total cost of the whole project for the tributaries of the Huai River is estimated at $30,000,000.

It is found that the total area which will be protected under the present scheme amounting to 20,000,000 mou. While the total cost of the project is estimated to be about $100,000,000, it shows that it averages only $5.00 per mou.

The foregoing tells only the general feature of the scheme. Detail study will be made only after sufficient data are at hand.

Article 4. Regulation of the Shu Ho.

The Shu Ho takes its rise in the Mengyi mountains in the province of Shantung. It has different local names along its course. It is called the Tasha Ho or Great Sandy River after it passes the town of Hungkwapu down to the border of the province of Kiangsu. Its course is divided into two branches at Shin Ho Chen in the district of Shuyang. The main course runs eastward, through the Tsingyi Lake (dried) and Rose River to the sea at Linhungkow. The other branch divides itself into two, called the Front and Rear Shu Ho, and again divides into ~~the~~ Kwantien Ho and Chaimee Ho. The Rear Shu Ho empties into the Tsingyi Lake too, while the Front Shu Ho and Kwantien Ho combine into one course, called Chiang Ho, and empty into the Rose River. The Chaimee Ho runs southeastward into the Yi River, and then finds its way to the sea. Since the valley of the upper Shu Ho is very steep that no natural storage can be offered by it. During the winter and spring seasons, the river bed is usually dried out, but in the summer season, the flood comes with such rapidity that the channel is unable to hold, and overflowing is usually occurred. In the former days such swamps as the Shuhsiang, Tsingyi, Tsengchu, etc., at its downstream side were still in existence, and could have offered as detention basins for the flood, but they are now all silted up, somewhere is even higher than the river bed, they can do more evils than good. This tells why the land traveled by the Shu Ho is always subject to flood, and many times, the flooded area merges into that of the Yi River to form a sea-like water body. The rivers, such as the Chaimei Ho and Shakiang Ho, etc., are always subject to the flood of both rivers and the condition of flood becomes worst if both rivers have an enormous flood meeting at the same time. It is plainly, therefore, in order to reduce the flood damage it is necessary to provide definite channels for the Shu Ho and Yi Ho separately going to the sea.

The Flood Magnitude.

According to the record of the former Kiang Huai Conservancy Board, great floods of the Shu happened both in the year 1921 and 1924. On July 15,1921, the maximum flood discharge was found to be 2,555 cubic meters per second at Maotsechuang, while on July 15,1924, measurement at Shinanchen indicated the maximum value to be 4,470 cubic meters per second, which is the highest record for recent years. It was confirmed by the people in the valley of the Shu Ho, that such a great flood had never been met with during the last several decades. By comparison with other rivers which have similar topographical conditions and nearly equal drainage areas, it is also shown to be a rare flood. Therefore the maximum flood discharge of the Shu Ho by which the schemes for flood control will base upon, is assumed to be 4,500 c.m.s..

General Scheme

Owing to incompleteness of the record of discharge measurement, no definite information can be obtained on the capacity of the channel of the Shu Ho at its lower course. By means of the maps and cross sections of the river, surveyed by the former Liang Huai Conservancy Board, an approximate estimation was made, showing that the channel of the Tasha River near Yenchiachih to be capable to discharge 880 cubic meters per second and that of the Rose River at Shachiafong being capable to discharge 180 cubic meters per second only. The capacity of the channel at the former place is only one fifth of that at the latter place, being still smaller, even not more than one twenty-fifth of the total maximum discharge of high flood. It is evident that the channel along its lower course is quite inadequate to carry the maximum flow and certainly inundation of the lands can by no means be avoided. But it is the fact that the rise and fall of the flow even during a high flood, are so sudden that its duration of flood peak lasts only a short period. Taking the high flood of 1921 for instance, on July 12 the discharge was found to be 39 cubic meters per second only, but three days after, that is, on July 15, it increased suddenly to 2,855 cubic meters per second. After that date it dropped very quickly to 505 cubic meters per second on July 19. Again in the Year 1924, on July 13, the discharge was 20 cubic meters per second; on July 15, it increased to 4,470 cubic meters per second; and decreased again to a value of 2,470 cubic meters per second on the next day.

And it was found to be only 247 cubic meters per second on July 17. After its high flood of short duration passes away, the channel often immediately reduces its flow to its minimum quantity or even wholly drying. In spite of its flood damage, it is equally not advantageous for both navigation and irrigation purposes. Moreover, whenever the terrible flood comes, it always carries down with it from the mountainous valleys much quantity of sedimentary materials which will silt up the channel at its lower course, causing the condition from bad to worse. In order to solve the problem of flood prevention of the Shu Ho satisfactorily, it is necessary to provide detention basins and a system of ground sills at its head waters. In th way its flood peak can be depressed, velocity be checked and quantity of silt be reduced. But the region at the head waters of theShu Ho ha never been carefully surveyed. Financial difficulty and time limitation together with disturbance due to bandits at that region had prevented us to carry on the survey. Therefor no definite scheme for the detention basins or system of ground sills can be made for the time being.

As to the lower course of the Shu Ho, the channel must nevertheless be improved for flood discharge whether regulation work is provided on its upper part, or not. The best way, as already stated before, is to separate the Shu Ho from the Yi Ho. The main channel of the Shu Ho is proposed to go along the Tasha Ho from Hunghwapu through the Tsingyi Lake and Rose River to the sea at Linhungkow. (See Fig.11) It is the shortest way with sufficient slope for discharging the flood.

At its junctions with other existing rivers, sluice gates will be provided to facilitate drainage and also to divert water for irrigation and navigation. As it has already been explained that the detail design can only be made after the survey is completed, hence for the present, based on the maps of the former Kiang Huai Conservancy Board we can only estimate the cost of channel improvement with the assumption that it is required to discharge the maximum flow of 4,500 cubic meters per second. This will give the maximum limit of the cost for regulation of the Shu Ho. It is known that the cost will be expensive if the channel is designed to discharge the maximum value of the flood peak without any means for detaining the flood. This has been fully discussed in the foregoing section in connection with the flood control of the Hui River. The cost of the final project, which is to be proposed after completion of the survey, must be far within the maximum limit.

The Cost of Channel Improvement for Discharging the Max. Flood Flow.

The present estimation is based on the assumption that the channel is called to discharge the maximum flood flow of 4,500 cubic meters per second. Its alignment is shown in Fig. 11. From Linhungkow up to the Tsingyi Lake the channel is 65.2 kilometers long, while its slope of water level is designed to be 1:10,330. From the Tsingyi Lake to Shuhokow it is 39.46 kilometers long and its slope is designed to be

1:7,900. From Shuhokow to Hunghwapu, its distance is 62.66 kilometers and its slope is 1:3,200. The channel at different section is designed accordingly. The cost of this project is summarized as follows:

Item	Quantity	Unit Cost $	Cost $	Remarks
Earthhwork for dikes	36,112,400cu.m.	0.16	5,777,984	Hauling Distance 100 m.
Earthwork for closing branches	70,000cu.m.	0.16	11,200	"
Sluices			200,000	
Land Compensation	177,000 mou	10.00	1,770,000	

Total.............$7,759,184

Article 5. Regulation of the Yi River.

The Yi River, being also taken its rise in the Mengyi mountains in the province of Shantung, enters the boundary of Kiangsu Province at Tanchen. After it passes Koushangchih, it divides into two courses. The main course runs southward to Chowchiakow, turns in the southeastern direction to the Loma Lake, and then flows eastward to Tashihtu to join the southern and northern Liutang Ho up to the towns, Wuchang and Lungkou, where it goes across the Salt Canal and finds its way to the sea through the Kwan Ho. The brance course was formerly regulated at its head by a movable dam called Lukowpa. Its water runs westward to the Middle Grand Canal in three different channels, their junction with the Grand Canal being Shutangchih, Shechiakow and Ertaokow. Small part of the flow in the main course is also diverted to the Grand Canal by way of the channel at Yaowan. Owing to the limited capacity of the channel of the Grand Canal, only a small part of the combined flow does run to the Inner Grand Canal. Main part of water returns again to the Liutang Ho through several cuts in the eastern bank of the Grand Canal, namely, Chiulungmiao, Wuhwachiao, Liulauchien, etc. During the high flood of the Huai River, part of the flood flow also finds its way to the Liutang Ho by way of the Changfu Ho and Salt Canal.

Formerly, regulators were constructed at Lukowpa and Yaowan. They were all destroyed. The former was used to regulate the flow in the branch course and as a safeguard to the Grand Canal. But after it was destroyed, the main current has found its way through the branch instead of the main course. Same is at Yaowan, where there was a regulator called Chulopa. After its destruction, the flow of the Yi runs freely into the Grand Canal. About one km. upstream of Chulopa, an escapeway of the Grand Canal was constructed to discharge surplus water into the Loma Lake. As the lake is entirely silted up, the flow from the escapeway runs at present directly southward to the Liutang River. During the high flood of the Yi Ho, a part of flood water finds its way through Shakiang Ho to the Shu Ho. The regulator at Liulauchien which acted formerly as an escapeway for the Grand Canal, is also not existed.

Flood Discharge

According to the record of the former Kiang Huai Conservancy Board, great floods of the Yi, have been also found in the year 1921 and 1924. In the year 1921, the maximum discharge was found at Liechiang to be 2,310 cubic meters per second, while in 1924 it was found at Lukow/pa to be 2,130 cubic meters per second. So far as the result obtained by actual measurement is concerned, the maximum flood discharge of the Yi Ho may be assumed at 2,310 cubic meters per second. But in comparing the valley of the Yi Ho with that of the Shu Ho which resemble almost in every respect to each other, this assumption seems to be a little bit too low to be adopted for design. Their topographical conditions are similar, and the rainfall in the two valleys are also not much in difference. Moreover they have the same torrential nature of the flood flow. Although the drainage area of the Yi Ho is comparatively larger, but its slope of the flow is less than that of the Shu Ho. Judging by these facts the probable maximum discharge of the Yi Ho can be by no reason less than that of the Shu Ho. Therefore for the sake of safety, it is assumed that the maximum discharge of the Yi Ho is also 4,500 cubic meters per second.

General Scheme

Since the main course of the Yi has been silted up, a large portion of its flood water below Chitseng has to find its way to flow into the Middle Grand Canal. As in the year 1921 the discharge at its upstream was found to be 2,510 cubic meters per second, while that portion which discharged to the Grand Canal by passing through Likowpa amounted at 1,900 cubic meters per second. The other portion which went southward along its main route was still partly diverted to the Grand Canal from Chulopa. But owing to the limited capacity of the silted channels leading to the Grand Canal and the worse condition of its main course, the flood water usually causes the inundation of the Yi Ho valley. As to the Middle Grand Canal which is also limited in capacity, the outlets at Chiulungmiao, Wuhwachiao and Liulauchien can not divert all surplus water eastward to the Liutang Ho on account of its silted condition. The combined flow of the Sze Ho and the Yi Ho usually has to overflow on both banks and causes the flood damage in the region of the Middle Grand Canal. Again the channel which discharges the flood water of the Yi Ho to the sea from the Main Liutang Ho along the northern and southern Liutang Ho to the Wuchang Ho and Lungkou Ho has its capacity gradually diminished as it flows toward downstream. That is a very bad condition for flood discharge. At Sanchatu on the Main Liutang Ho the capacity of the channel is about 1,300 cubic meters per second, while at the place near the upstream of the junction of northern and southern Liutang Ho, it is only 750 cubic meters per second approximately, and the total discharge in Wuchang Ho and Lungkou Ho is also only that much. Since the flood flow can not entirely pass away to the sea at its downstream, the land in the valley of the Liutang Ho is surely subject to inundation. In case a part of the flow passes eastward to Shakiang Ho, that will make the case more severe in the flood area of the Shu Ho valley. In a word, since there is not a proper channel of adequate capacity to pass flood water of the Yi Ho to the sea, it often causes great damage in case of flood to the region north of the Old Yellow River. The first thing to be done for the regulation of the Yi Ho is then to provide a channel to the sea.

The Middle Grand Canal, led water from the Wishan Lake, is the only waterway for the drainage of water in the southwestern part of the province of Shantung. For the sake of flood control in Shantung and also the valley of the Middle Grand Canal, only the Sze Ho will be permitted to flow through the Grand Canal. Flood water of the Yi Ho must be separated from it. The course of the flood channel of the Yi Ho is proposed to pass along its original main course from Koushangchih to Chowchiakow and then to flow southward through the Loma Lake to Sanchatu, whence by combining with the portion of flood water of the Sze Ho which is to be diverted from Liulauchien (See next Section on Regulation of the Sze River) it runs eastward along the Main Liutang Ho to Chienchiachih. Then by the passage through the Northern Liutang Ho, Lungkou Ho, and Kwan Ho, it discharges into the sea. All the channels which lead its flood water to the Grand Canal, are to be closed except one which is to be retained for supplying of the Grand Canal in case of drought. Since the discharge capacity of the flood channel except the Kwan Ho section is everywhere much less than the maximum value to be provided, its channel section must be increased either by excavation or by construction of dikes.

The probable maximum discharge of the Yi Ho is 4,500 cubic meters per second and that actually measured in the year 1921 amounted to not less than 2,310 cubic meters per second. But the condition of the Yi Ho is just the same as that of the Shu Ho that it has a steep valley at its upstream without a place for detention. Although its flood peak is high, but its duration is rather short. For instance in the year 1921, on Aug. 2, its discharge was found to be 65 cubic meters per secondonly, on Aug. 7, it suddenly increased to 2,310 cubic meters per second. But on Aug. 10, it decreased again to the amount of 360 cubic meters per sedond. Also in the year 1924, the discharge amounted to 194 cubic meters per second only on July 24, but it raised to its maximum 3,130 cubic meters per second on July 26. Then the flood lowered again to the amount of 977 cubic meters per second on July 30. Therefore for the regulation of Yi Ho, same as in the case of the Shu Ho, not only it is necessary to improve its channel at the downstream side, but also it is required to provide detention reservoirs and ground sills at its upstream side. By this way flood water will be partly stored up and its velocity checked. The cost of the channel improvement will be minimized and at the same time, irrigation can be developed. But the survey at its head water is not yet completed. No definite scheme can be laid down for the location of detention basins and system of ground sills at present. For estimating the max. limit of the cost of regulation work, as in the case of the Chu Ho, it is designed to pass the maximum discharge for the channel improvement. For this computation, the topographical maps and cross sections of the channel at its downstream side surveyed by the former Kiang Huai Conservancy Board are used.

The Cost of Channel Improvement For Discharging the Maximum Flood Flow.

The course of the flood channel for this estimation is shown in Fig. 12. It is designed to pass the maximum flood peak value of 4,500 cubic meters per second. For simplicity of description, we may divide it into three sections. The first section is from Chitseng to Sanchatu. Its discharge capacity is designed for 4,500 cubic meters per second, its slope of flow is from about 1:5,700 to 1:7,300 the width of the channel between dikes is from 600 to 790 meters, the height of dikes is increased on the average 0.4m., and its depth of flow is from 5 to 6 meters. The second section is from Sanchatu to Lungkou. With the additional flow of 1,000 cubic meters per second from Liulauchien(See next section), the maximum discharge for this section and its downstream amounts to 5,500 cubic meters per second. The slope of flow for this section is about 1:10,500, its average width between dikes is 916 meters, the height of dikes is from $3\frac{1}{2}$ to 6 meters, and the depth of water is from $5\frac{1}{2}$ to 8 meters at its middle portion of the channel and from 2 to 4½ meters near the banks. The last section is from Lungkou along the Kwan Ho to the sea. Since the existing channel of the Kwan Ho is large enough, not much money will be spent for this section. The average width of the channel in this section is about 1,400 meters; the height of dikes, from 1 to 5.5 meters, and its depth is from 7 to 11 meters at the middle and from 0.5 to 3.0 meters near the banks. The total cost is summarized as follows:

Item	Quantity	Unit Cost $	Cost $	Remarks
Earthwork for dikes	43,540,000cu.m.	0.16	6,966,400	Hauling distance 100m.
Earthwork for closing branches	500,000cu.m.	0.16	80,000	"
4 sluices			200,000	
Land compensation	235,000mou	10.00	2,350,000	

Total............... $9,596,400

Article 6. Regulation of the Sze Ho and the Rivers and Lakes in the Southern Shantung Province

The Southern Grand Canal in the Province of Shantung receives all the streams from the mountain ranges of Tai Shan, such as the Wen, Sze and other small streams in the districts of Teng and Chow. The Chu, Wanfu and Chungti Rivers in the district of Tsaochow also drain into it. The outlets for the Grand Canal are the Yellow River in the north and Yangtze River in the south. Its northern outlet is not an efficient one for the Yellow River bed is silted up higher and higher that its dike is at present four meters higher than the bottom land. In consequence, the triangular shaped region enclosed by dikes of the Grand Canal, old and new Yellow Rivers resembles a water basin, with only one outlet through the Wishan Lake. Nine districts in the west of the Grand Canal are always subjects to inundation, and much more severely damaged in thdyear af bigger flood. The land on the east of the Grand Canal, on account of its higher topography, is in a better condition except the district of Tungping, which is permanently inundated by the Wen Ho. The peopleof the province of Kiangsu, being on the downstream side, are constantly in fear of the rivers and lakes in the provinceof Shantung being improved and drained into their region. In the present scheme, it is proposed to regulate the Huai and Yi Rivers separately, the Middle Grand Canal will only be used to discharge flood water from the Shantung province till Liulauchien where it finds its way to the sea by the Yi Ho. Bythis means, the flood problem in the province of Shantung can be hopefully solved.

All the streams running southward from the province of Shantung are all temporarily detained in the Wishan Lake. According to the topographic map of 1:100,000 scale, it is roughly estimated that the lake area is 370 sq.km., enclosed by the 31m. contour line, and is 870 sq.km., enclosed by the 35m contour line. The general elevation of the lake bottom is about 30.6m. Hence the capacity of the lake between 31 to 35m is approximately 2,480 mill. cu.m., which is quite sufficient to be utilized for floodcontrol and storage purposes, as in the case of the Hungtze Lake.

The Flood Magnitude

The present channel leading to the Yellow River for the Wen Ho will be maintained. The inundation of the district of Tungping will be relieved by another way. Hence the flood quantity of the Wen Ho is not included in the estimation of flood magnitude for the Southern Grand Canal in Shantung. The exact value of inflow to the Wishan Lake is not known for lack of data. The stream measurement made by the Shantung Grand Canal Board shows that the largest discharge of the Sze Ho in the period from 1913 to 1916 was 748 cu. m. per sec. Since the drainage area of the Wishan Lake is approximately 30,000 sq. km., while that of the Sze Ho is about 4,060 sq. km., so if the same rate of flood flow as that of the Sze Ho be applied to the whole area then the max. flood inflow of the lake would be 5,500 cu. m. per sec. However, because of the hilly topography of the Sze Ho valley, the discharge on unit area must be high, so a general application of its rate to the whole area will give a value too large for use. Moreover, this max. flood of the Sze Ho is short-durated, lasting only one day. Now, with the big storage capacity of the Wishan Lake, it is enough to detain the flood flow. Only the total inflow or the average outflow of the lake during the flood period will be taken into calculation for regulation work.

According to the report of Ze-Ka-Wei Observatory, the precipitation of the drainage area of the Wishan Lake during flood season is nearly the same as that of Tsingtao. From the records of that station, the maximum precipitation occurred always in the months of July and August. The maximum values recorded were 295.3 mm. and 280.5 mm. respectively, hence the total value of these two months was 576 mm. Also there is no record upon the relation between rainfall and run-off in this drainage area to be studied, we can estimate the ratio only by experience. For safety, this is assumed to be equal to 40%, as that is the maximum ratio ever occurred. Since the drainage area of the Wishan Lake is about 30,000 sq. km., the total discharges during these two months will be 30,000,000,000 x 0.576 x 0.4 = 6,900,000,000 cu.m. or in average 1,330 c.m.s.. The flood peak of maximum discharge is still unknown, but we can make that the outflow of the lake will not be affected by the inflow directly since the Wishan Lake can detain a certain amount of flood discharge. Suppose we fix the highest lake level at 36m, that in 1921 being 35.56m. then we have a storage capacity of 2,480 million cu. m. between the lowest and highest lake levels. The total outflow discharge during July and August will be 4,420 million cu. m. or 853 c.m.s.. For safety, we take 1,000 c.m.s. as the outflow discharge of the Wishan Lake.

Flood Control Project

There are two outlets for the Wishan Lake. One is at Changkoshan, where it is controlled by a dam called Lingchiapa. Below that, the Pelau Ho conveys water to the Middle Grand Canal in Kiangsu at Shutangchih. The other outlet is at Hanchuang, where there is a regulating structure of 14 openings for regulating the inflow and also as a check dam in the main canal below the regulator. The former channel has been very much silted up, the maximum discharge in the year 1931 was only 135 c.m.s. while the lake level reached to 35m. Also its distance between the lake and Chutangchih is longer than that of the Middle Grand Canal, hence it has a flatter slope. The latter channel, from Hanchuang down through the Middle Grand Canal, therefore, is selected as the flood channel for the Wishan Lake. But as the Middle Grand Canal will also be used as a navigable waterway, the navigable depth and discharge should also be considered in the flood control project. For the navigation in dry seasons, we shall construct locks at Teshenchai, Hotingchai, Liulauchien, etc. as will be described in the chapter on navigation projects.

The flood flow of the Wishan Lake will be discharged from Hanchuang through the Middle Grand Canal, Yi Ho, Liutang Ho, Lwan Ho, and then to the sea. From a study of the topography of the Yi Ho and Grand Canal, the best way is to divert flood water from the Grand Canal at Liulauchien. A movable dam to discharge 1,000 c.m.s. is proposed to be constructed on the eastern dike of the Grand Canal just upstream of Liulauchien Lock. Below that dam, the flood flow will follow the old channel eastward and meet with the Yi Ho at Sanchatu. The regulator and other Chai's at Hanchuang and along the Middle Grand Canal should all be demolished as to be convenient both for flood flow and navigation. Movable dams should be constructed at the sides of the locks at Teshenchai and Hotingchai as to regulate the flood flow.

The highest water level of the flood channel of the Yi Ho at Sanchatu will be 18m. Let the total loss of head due to the movable dam at Liulauchien and in the channel between Liulauchien and Sanchatu to be 1m, then the water level just above that dam will be 19m. The distance between Liulauchien and Hotingchai is 97 km. The slope in this portion is used as 1 in 13,300, which is the most economical slope obtained as it will utilize most of the existing channels. Then the water level just below the movable dam at Hotingchai will be 26.28m. Let the loss of head due to this dam be 1m, the water level just above the dam will be 27.28m. The distance between Hotingchai and Teshenchai is 45.5 km. By the same reason let the slope in this portion be 1 in 9,000 and loss of head over the dam be 1m, then the water level below that dam will be 32.33m and that above the dam will be 33.33m. The distance between the Teshenchai and old sluice gate at the lake mouth is 11.63 km. Let the slope in this portion also be 1 in 9,000, then the water level at the lake mouth will be 34.62m. This means that when the lake level reaches the above value, its outflow discharged will be 1,000 c.m.s. This is on the safe side, otherwise if the outflow reaches its maximum value until the lake level has raised to the highest gage, then the great amount of storage water in the lake will cause inundation in its upstream side.

For safety to navigation, the velocity of flow should not be more than 2 m/sec. with the maximum discharge of 1,000 c.m.s. With the above mentioned slopes being used, then the minimum cross-section for the portion between the lake mouth and Hotingchai according to Prof. Forchheimer's formula, will be:

bottom width	50m
top width	82m
mean depth	8m
side slopes	1:2

That from Hotingchai to Liulauchien will be:

bottom width	64m
top width	96m
mean depth	8m
side slopes	1:2

According to the existing cross-sections of the Grand Canal, not much dredging work is required except the width of the portion between the lake mouth and Toshenchai and the depth of the portions just below Toshenchai and Hotingchai should be increased. Since the hgihest water level will be higher than the ground surface, then the height of levees should be increased according to the highest water level along the Grand Canal as shown in Fig. 14. Let the top width of the levee be 4m. its freeboard be 1.5m, and its side slopes be 1 to 3.

From Liulauchien to Sanchatu, for economical reasons, the old channel should be fully utilized. The distance in this portion is 11 km., max. discharge will be 1,000 c.m.s., and let its slope be 1 in 20,000. According to Forchheimer's formula, its standard cross-section will be:

bottom width	80m
top width	112m
mean depth	8m
side slopes	1:2

In this portion, excavation and embankment should be provided from Liulauchien to Yuantu of a length 4.37 km., and only embankment should be provided from Yuantu to Sanchatu of a length 6.62 km. The levee section will be the same as that for the Middle Grand Canal.

The Pelau Ho will not be closed. It will be used for water supply purpose along its course. We shall construct a sluice gate at its mouth for regulating its flow. Also a sluice gate in the Middle Grand Canal should be constructed adjoining the lock at Liulauchien for regulating the irrigation water downstream. These two sluice gates cost about $150,000.

The total cost for three movable dams at Teshenchai, Hotingchai, and at the eastern dike at Liulauchien is estimated to be about $500,000.

The costs of the flood control project on the Sze Ho and Southern Shantung rivers are summarized as follows:

Excavation between Liulauchien and Sanchatu	973,600cu.m.@$0.135 =	$131,436
Embankment on the same	526,200cu.m.@$0.16 =	$ 84,192
Excavated material used for embankment on the same	261,300cu.m.@$0.025 =	$ 6,533
2 sluice gates at the mouth of the Iclau Ho and Liulauchien		$150,000
3 movable dams at Teshenchai Hotingchai and Liulauchen		$500,000
	Total................	$872,161

This project is mainly for providing the flood outlet of the Southern Shantung rivers. Other schemes as to improve the rivers for drainage and irrigation are not included for lack of data.

Chapter. III. Navigation Projects.

Article 1. Introduction

Canalization of Rivers.

Within the district of the Huai River and Grand Canal, streams and water bodies are so numerous that navigation by small junks are very much generalized. The well-known rivers and lakes are the Grand Canal, Salt Canal or Yen Ho, Changfu Ho, Hungtze Lake, Kao Pao Lakes and the Huai River proper. They are the important waterways for the transportation of native goods, and small boats are to be seen everywhere. But they are all of natural water courses, so that their navigable depths are subject to the fluctuations of the water surface. In the wet season they are of course deep enough for the comparatively big boats; but during the dry season, since the source of water supply is greatly limited, and at the same time the flow is not in any way checked from running into the Yangtzekiang or the sea, they soon become too shallow for navigation. This is the reason why navigation in this district are scarcely developed to a great extent.

In the former days when the Grand Canal was called upon to transport the rice tribute for the Royal family, it was built many Chai's (movable dams of the stop log type) in the canal to raise the water surface in the different pools, such as Yunliu, Hoting and Weichi, etc. Up to the present, even such Chai's are still in existence, but they are nearly all out of repair that the stop logs are not to be put down even in the dry season. They can serve no purpose. Besides those Chai's, we have the Sanhopa at the southern end of the Ming Dike on the Hungtze Lake. It is built every year as soon as the flood season is over in order to compel water of the Huai River to flow into the Grand Canal by way of the Changfu Ho. At the lower end of the Grand Canal, there are several flood escapes with flash boards made of weeds and earth to check the flow of the Grand Canal from being lost into the Yangtze Kiang or the sea after a flood season is over. Temporary earth dams are also to be found in the rivers to check the flow during dry season, such as near Tsematou on the Salt Canal. All these means are for the conservation of water quantity for the use of navigation. Nevertheless, they are all crude in form and sometimes contracting the channel so much as to cause tumultuous flow at the opening that boats are to be towed up and down with great difficulty. In many cases the navigation routes are entirely cut away, that trans-shipping is necessary at these places.

For navigation purpose, in order to prevent the interruption of traffic a river should have a sufficient depth of water for the whole year to be consistent with the draft of the biggest boats. But for the natural water courses, the variation of water level is very great, and it is quite uncertain as to the duration of time when there is a sufficient depth of water for navigation. For example on the Middle Grand Canal at Yaowan (see Fig. 17) the duration of time for the continuance of water level is different throughout the year. On this portion of the canal the deepest part is 15m in elevation. In average there are 77 days (21% of the year) when it is three meters in depth; 118 days (32% of the year), when it is 2½ meters in depth; 186 days (51% of the year) when it is 2 meters in depth; and 57 days (15½% of the year) when the water level ever reaches the record of 19.7 meters. Hence it is quite clear that water is deficient for the navigation of big boats throughout the year. But the way to increase the depth of water by deepening the channel is not possible, because during the dry season, the water source is quite limited, and if the channel is excavated to a steep slope, the velocity thus acquired will soon cause the water level to be quickly lowered. It is true that a river can be excavated to increase its tidal effect, but it should be quite near to a tidal river or the sea, and it is an impossibility to excavate a river of several hundred miles long such as the Grand Canal to such a depth that the channel will be below the mean water level of the sea to fetch the tidal effect. Hence the way to preserve sufficient depth of water for navigation is to canalize the river by building locks and movable dams along its course to regulate its flow.

For example, if a lock and a movable dam are constructed on the Middle Grand Canal at Yaowan, what is formerly considered as the highest water level to be occurred only 57 days of the year can easily be changed to be the lowest water level. According to the past records (see Fig. 23) the lowest water level at some parts of the Middle Grand Canal nearly coincides with the canal bed, that is at those parts the canal is wholly dried up during the dry season. But after proper improvement is given, the minimum depth of water will reach 3 meters, so that boats with 900 tons of freight can easily navigate throughout the year.

A movable dam is so constructed that it can be opened and shut at will. When a river is controlled by movable dams, sufficient depth of water can easily be preserved for navigation during the dry season. By the side of the movable dam, a lock is built. It has two sets of gates at the upper and lower ends of the lock chamber. When a boat is decending from the upstream, water is first conducted into the chamber till the water surface is even with that of upstream. Then the gates at the upstream side is opened for the boat and shut as soon as it has reached the chamber. The water in the chamber is then led out to the downstream, so that the water surface in the chamber and that of downstream will be on the same level. The gates at the downstream end is now opened for the boat to pass. The process will be similar when a boat is ascending from the downstream. During the flood season, both the movable dam and the lock are opened for flood discharge, so the condition of the natural water course is resumed.

The Navigation System

Before dealing with the individual navigation projects, let us describe the navigation system at first. (see Fig. 19)

The Grand Canal running from the northwest to southeast and terminating at the Yangtze River forms one of the main navigation routes of the system. In the first period of construction, five locks are to be built along the course from Chunchiakow on the Wishan Lake down to Huaiyin, Shaopai and Sankiangying which is on the Yangtze. In future, when the Yellow River in the Province of Shantung is improved, two more locks, one at Chunchiakow and another at Chiangchiakou on the Yellow River. Moreover, after a lock is constructed at the junction of the Chuangchang Ho and Tungyang Canal, and another on the proposed irrigation canal between Yenchen city and Chinghochai, the boats on the Grand Canal and those latter streams can be mede intercommunicable.

Another main navigation route will run from the southwest to northeast and terminate at the sea. It consists of a series of rivers and lakes, namely, the Huai River, Hungtze Lake, Changfu Ho, Salt Canal and Kwan Ho. Besides the Huaiyin lock, which is used for the both main routes of navigation, three more locks will be built during the first period of construction, one is at Tsaikungtu and Shinpuchen, on the Salt Canal and at Langkou on the Kwan Ho. In future, if another lock be built at Fushan or Huaiyuan on the Huai River, the navigation route can still be extended further upstream. At Kaoliangchien, the proposed irrigation canal from the Hungtze Lake to Chinghochai, one lock is needed in order to shorten the navigation routes from the upper Huai River to the Yangtze River. During the flood season, boats can directly pass through the San Ho to the Yangtze by means of the lock at the proposed regulator at Chiangpa.

The Predication of Future Transportation

When the navigation system is well developed, transportation and commerce are sure to prosper. According to Prof. Franzius' estimation, the Grand Canal after improvement for 5 years, will have an annual freight of 5,000,000 tons, and after 25 years, will increase to 20,000,000 tons, because its vast collecting and distributing area, the suitability of the location, and cheapness of labor will make the development quicker than usual. If the navigation between the Huai River and Salt Canal is to be connected, same development will be occurred. Hence we can expect that after the 5 years since the completion of the work, annual freight of 10,000,000 tons will be reached. There is no accurate statistics of the present transportation on those rivers, but from a conservative estimate, it is about 1,000,000 tons. That means, after 5 years, the transportation will increase ten-folds.

The Minimum Cross-section for the Canalized Rivers.

The size of a navigation canal should base on the size of boats. During the Ching Dynasty, when rice tribute were transported on the Grand Canal for the Imperial family, Chai's were constructed to preserve a sufficient depth of water for the navigation of large boats. But with the suspension of imperial service the Grand Canal is lack of care, so very few big boats are now to be seen. As the Inner Grand

Canal is comparatively much deeper, boats with 150 tons are still in use, but they can only reach Shaopai because beyond that place, the canal becomes shallower.

Now the design of a navigation canal should base on the necessities of the immediate future, and shouldnot be over-sized. Since the big freight ships can not be introduced until there are dense networks of railroads, highways and waterways at the principal centers of freight. By this way, the freight can be greatly centralized, and the use of big ships can be found profitable. But for the present, even the milage of public roads is rapidly increased, yet still there is time before the completion.

In the present scheme, the largest ship we assume for future use is 72 meters long, 9 meters wide and 2 meters of draft. Assuming the ratio of fineness (Voelligkeitsgrad) to be 0.88 and ratio of tonnage (Tragfachigkeits ziffer) to be 0.80, then its tonnage will be 72 x 9 x 2 x 0.88 x 0.80 = 910 metric tons or 900 long tons. The design of the channel for such a canal is to admit two boats to pass side by side. Hence the width of the canal bed should be 20 meters, and the minimum depth of water, 3 meters, with one meter clearance between the bottom of the canal and that of the ship. The typical cross-section is shown in the following figure (Fig. 18).

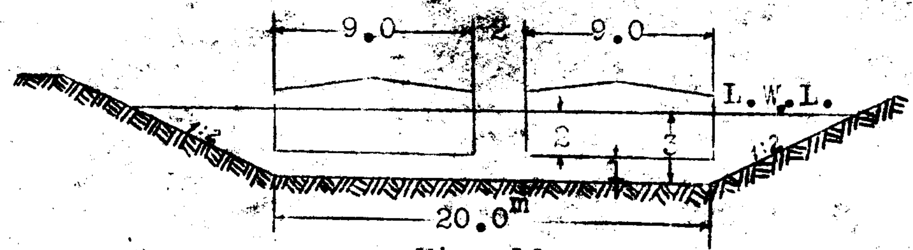

Fig. 18

Near the entrance and exist of a lock, the canal should be widened for the anchorage of ships, and also these must be a straight stretch as to give a clear view for the shippers. In the first period of development, we adopt the length of the stretch to be one kilometer, and the width of the canal bed, 40 meters.

The Dimensions of Locks

The lock of the first period of development will be designed for the necessities of the immediate future. In future with the increase of size of ships and freight it will naturally call for locks of larger size to be installed. Here we adopt the length of the lock chamber to be 85 meters, the width of the lock chamber, 12 meters and the minimum depth of water at the sill, 2½ meters. One of the largest boats can pass through it at one time; for boats of 8 meters wide, 32 meters long and 2 meters of draft with a tonnage of 225 metric tons, four of them can pass at one time; for boats of 3 meters wide, 20 meters long, and 1½ meters of draft with a tonnage of 60 metric tons, six of them can pass at one time; and for the common sized and small boats, more than ten of them can pass at one time. After the introduction of larger sized locks in future, they can still be in use for small steam-boats and passenger boats, because at each operation they require very little volume of water, and are easy to be manipulated.

Locks are to be opened once each hour. For a navigation canal, the water for lockage at each operation of the locks including the seepage and evaporation of the canal is estimated to be 20 cubic meters per second. This volume of water is neglected during the flood season, but even during the dry and irrigation season it can easily be supplied.

Navigation during the Flood and Irrigation Season.

Although the flood channel of the Huai Ho below Hungtze Lake is separate from the navigation channels, yet all other principal rivers within the district of the Huai Ho and the Grand Canal are so regulated that the flood of one river is conducted to the other during the flood season. Thus the flood of Sze Ho is conducted to flow down the Grand Canal as far as Liulauchien; the flood of Yi Ho, to Kwan Ho; the flood of Chu Ho, to Yen Ho below Shinpu; and the flood of the Huai Ho to its main channel above the Hungtze Lake. Hence during the flood season all locks and movable dams should be opened to discharge the maximum volume of water, and at the same time to maintain a favorable condition for navigation. Even if navigation is suspended by floods, little harm is done, because the duration of flood season is rather short.

During the irrigation season, the Changfu Ho, the Middle Grand Canal below Liulauchien and the Inner Grand Canal are used both for irrigation and navigation purposes. At that time with the sudden increase of water, the water level at some portion of the river will rise, while that at the other portion will fall. Hence in order to avoid inconvenience to navigation, the shallow portion should be excavated so that the minimum depth of water will be three meters .

The Correction of Curvature.

For a natural water course, there are usually some sharp bends. Even if the river has been canalized and the velocity of current controlled, they will still give much inconvenience to navigation, so they should be corrected, and the radius of curvature should not be less than one kilometer.

The General Design of Lock and Movable Dam

Locks adopted for the navigation canals and rivers are similar with each other, and the sites selected for their installment will be discussed later on. Now since the topographical features of those sites have not yet been carefully surveyed, detail plans of each lock for the particular site cannot be made, so only two typical designs are shown in Figures 20 and 21. The maximum lift for one lock is 9.2 meters, and for the other, 6.7 meters.

The lock foundation is for the most part of sand and clay. Its bearing power is to be investigated at the site of construction. Now assuming the bearing power to be 4,000 pounds per square foot, the dead load of the lock should be reduced so as to decrease the expense of the foundation construction. So reinforced concrete is used, the lock walls have been designed with counterforts on the back, and its floor reinforced with rib beams in one case. In order to increase the safety of the structure, cross beams are added between the counterforts and rib beams perpendicular with each other, so that the earth and water pressure can be equally distributed among the beams, and if there is any accidental collision due to ships, the force can be speedily transmitted to all parts of the structure.

As the lock walls are easily subject to impact, so in the calculation of stress the water pressure is increased by one third. The protection of the reinforcement is made with extra thickness, so that any breakage caused by accident can be easily repaired.

The lock has two pairs of miter gates made with structural steel. Hand manipulated machines are used for the operation of lock gates and water passages.

When a navigation canal is used to discharge the flood of another river, the movable dam which is installed by the side of the lock should be larger than usual. But if it is only used to discharge rain water or to control water for navigation, a sluice or a dam smaller in size will equally serve the purpose.

Article 2. The Navigation Project of the Grand Canal

In our first period of navigation development for the Grand Canal, works of improvement will be done beginning from Chunchiakow on the Wishan Lake of the Shantung Province to Sankiangying on the Yangtze River for a total length of 430 km. Along its course five locks are to be constructed, namely Teshen Lock, Hoting Lock, Liuchien Lock, Huaiyin Lock and Shaopai Lock. From Chunchiakow to Liuchien Lock, water is supplied by the Wishan Lake and from Liuchien Lock to Shaopai Lock, water is supplied both by the Wishan Lake and Hungtze Lake.

As the Grand Canal from Chunchiakow to Chiangchaikou on the Yellow River for a length of over 150 kilometers has not yet been carefully surveyed, no schemes of improvement can be made, but generally the construction of two locks at the two places above mentioned will sufficiently accommodate the navigation between these two rivers. After the completion of these two locks the intercommunication between the Yangtze River and the Yellow River will be possible. It will be done after the first period of navigation development.

Below Shaopai there are two water channels flowing towards the Yangtze River: one is used for the proposed flood channels of the Huai River beginning from Liuchai, and passing through the Taiping Ho, Liochiakou and Shatou Ho to Sankiangying, while the other passing through Yangchow to Kuachow to join the Yangtze River. After the completion of the flood channel, the water depth below Liuchai will be enough for the navigation of large boats and further excavation is unnecessary. The other channels to Kuachow may be too shallow to accommodate the navigation between the Grand Canal and the Yangtze River during the dry season, yet it is of minor importance, so the scheme for its excavation is omitted.

In describing the proposed schemes, the portion of the canal below each lock is considered to be a section, and the engineering works of the six sections will be discussed in detail in the following pages.

The First Section: from Chunchiakow to Teshen Lock

For navigation purpose the portion of the canal from Chunchiakow to the outlet of the Wishan Lake should be excavated, while below the outlet excavation is also in need, as the canal is used for flood discharge. A lock will be constructed at Chunchiakow in future to be named Chunkow Lock.

As the Grand Canal meets the Tientsin-Pukow Railway line at Hanchuang, this town will be expected to become a commercial centre. The bridge and rails at the crossing should be reconstructed and raised five meters higher in order to make room for the canal boats.

The length of the canal from Chunchiakow to Teshen Lock is 37.5 kilometers. The estimate of the total expenses including the excavation of the channel for flood discharge is given in the following.

Excavation of the channel 7,168,188 cu.m. $967,705

Dike construction with excavated earth, ramming only	1,102,046cu.m.	$ 27,551
Dike construction with borrowed earth ramming included..	57,554cu.m	9,209
Reconstruction of rails and bridges		50,000
	Total.......	$1,054,465

The Second Section: from Teshen Lock to Hoting Lock.

The railway constructed by the Chung Shing Coal Mining Company meets the Grand Canal at Taichuang. After the canalization of the Grand Canal is completed, Shantung coal will find the markets in all the towns and cities in the regions of the Huai Ho, the Grand Canal and the Yangtze River. This portion of the canal should be so regulated that the variation of water level for the whole year will be 0.5 meter, that is, the highest water level will be 28.9 meters and the lowest water level, 28.4 meters. The maximum lift of the lock will be 6.7 meters and the minimum lift, 1.7 meters. During the flood season, the difference of water level is to be reduced to one meter. The length of the canal from Teshen Lock to Hoting Lock is 45.5 km., and the estimate of the total expenses including the construction of Teshen Lock is given in the following:-

Construction of Teshen Lock		$300,000
Excavation of the channel	3,300,262 cu.m.	445,535
Dike construction with excavated earth, ramming only	555,844 cu.m.	13,896
Dike construction with borrowed earth, ramming included	2,015,856 cu.m.	322,537

Total..................$1,081,968

The Third Section: from Hoting Lock to Liuchien Lock

At this portion of the canal much difficulty is felt for navigation during the dry season, because for the whole year there are only a few days when there is a sufficient depth of water for the navigation of large boats. Figures 17 and 23 will clearly show these difficult features.

The Pelau Ho which joins the Grand Canal at Taichuang also unites with the Wishan Lake at its west bank. Though this river is now quite shallow, yet when the water level of the Grand Canal has been raised, it is easy to be improved for navigation, so as to accommodate the communication with interior towns and cities.

The Lung Hai Railway line crosses the Grand Canal at the south of the Pelau Ho. Though there are now no important towns in the neighborhood, yet when the navigation system of the Grand Canal has been developed, it will be the linking place for communications by land and by water, and the bridge and rails at the junction of the canal with the railway line should be raised six meters higher in order that ships may be able to pass.

This portion of the canal should be so regulated that the variation of water level for the whole year will be 0.5 meter, that is, the highest water level will be 20.2 meters and the lowest water level, 19.7 meters. The maximum lift of the lock will be 9.2 meters, and the minimum lift, 8.2 meters. During the flood season, the difference of water level is to be reduced to one meter. The length of the canal from Hoting Lock to Liuchien Lock is 104 kilometers, and the estimate of the total expenses including the construction of Hoting Lock is given in the following:-

Construction of Hoting Lock		$400,000
Excavation of the channel	2,476,974 cu.m.	334,391
Dike constuction with excavated earth, ramming only	569,950 cu.m.	14,249
Dike construction with borrowed earth, ramming included.	1,978,120 cu.m.	316,499
Reconstruction of a bridge and rails		50,000
Total...........................		$1,115,139

The Fourth Section: from Liuchien Lock to Huaiyin Lock.

Since the water of the Hungtze Lake flows to the Grand Canal through the Changfu Ho, so for this portion of the canal the variation of water level is very grat, the highest water level being 16 meters and the lowest water level, 11 meters. The maximum lift will be 9.2 meters and the minimum 3.7 meters. From Liuchien Lock to Chungshin the channel needs little excavation, but below Chungshin the existing channel of the canal is so crooked that a new channel to connect with the Inner Grand Canal is necessary (See Fig. 26). With the completion of this new channel and the improvement of the Changfu Ho, boats from the Grand Canal can easily navigate to the upper part of the Huai Ho and one of the three Chai's near Matou, namely Weichi, Tungchi and Fushing Chai's can be reconstructed and used as sluices during the flood season. The length of the canal from Liuchien Lock to Huaiyin Lock is 57.5 kilometers and the estimate of the total expenses including the construction of Liuchien Lock is given in the following:-

Construction of Liuchien Lock		$400,000
Excavation of the channel	2,207,082 cu.m.	297,956
Dike construction with excavated earth, ramming only	170,020 cu.m.	4,250
Dike construction with borrowed earth, ramming included	80,674 cu.m.	12,908
	Total...............	$715,114

The Fifth Section: from Huaiyin Lock to Shaopai Lock

This portion of the canal is longest among the six sections. At its north extremity is Huaiyin, which will be the communication centre for the surrounding towns and cities. The Grand Canal communicates with the Yangtse River in the south, and the Shantung Province in the north connects with the Tientsin-Pukow and Lunghai Railroad lines, flows to the sea through the Yen Ho and Kwan Ho at the east, and joins with the Hungtze Lake through the Changfu Ho at the west. Along its course there are many important towns and cities. Hence after it has been regulated and improved, the development of commerce and communication and also the improvement of living conditions of the surrounding towns and cities can be predicated.

There are now small steam-boats running between Huaiyin and Chinkiang. The portion of the canal below Kaoyu is quite deep for navigation throughout the year, but from Kaoyu to Huaiyin there are only a few months out of the whole year when there is sufficient depth of water for navigation. But after the improvement, there will be no more of such inconvenience.

The variation of water level for this portion of the canal is 0.5 meter, that is, the highest water level will be 7.3 meters and the lowest water level, 6.8 meters. During the irrigation season, the water surface will acquire a natural slope as the water level near Huaiyin Lock will be 10 meters, while that near Shaopai Lock, 5.87 meters. The maximum lift of the Huaiyin Lock will be 9.2 meters, and the minimum, one meter. The channel between Huaiyin and Huai-an is to be enlarged. The length of the canal between Huaiyin Lock and Shaopai Lock is 145 kilometers, and the estimate of the total expenses including the construction of Huaiyin Lock is given in the following:-

Construction of Huaiyin Lock		$400,000
Excavation of the channel	666,074 cu.m.	89,920
Earth fillingon the western Dike	80,000 cu.m.	12,800
Total....................		$502,720

The Sixth Section: from Shaopai Lock to the Yangtze River.

Between Shaopai and Liuchai a new channel is excavated to join with the flood channel of the Huai Ho at Liuchai and to flow through the Taiping Ho, Liochiakou and Shatou Ho to Sankiangying on the Yangtse River. The old channel will be used as the headbay for the Tungyang Canal.

At the upstream of Shaopai Lock, the water level at normal times is from 7.3 to 6.8 meters, the variation of water level being 0.5 m. But during the irrigation season it will be reduced to 5.8 meters. As to the water level at the downstream of the lock it cannot be ascertained, because the rise and fall of water level has an intimate relation with the tidal effect of the Yangtse River and the volume of water coming from the flood discharge channel of the Huai Ho. But when the water level of the Yangtse River is at its lowest, the water level of this section will be 0.4 meter. The maximum lift of the lock is then 7.7 meters, and during the maximum discharge of the Huai Ho, the highest water level at the downstream of the lock will be 7.5 meters, being 0.2 meter higher than that of the upstream. At that time the lock should be opened so as to give a free passage for boats.

Taiping Ho when used for flood discharge should be so excavated that the elevation of the canal bed will be -4.0 meters. Liochiakou and Shatou Ho are very deep that at the lowest water level of the Yangtse River, the depth of water is over three meters, and at normal times it may be six to seven meters, so steam-boats coming from the Yangtse River can directly reach Liuchai. So no dredging works for its improvement is necessary.

The portion of the canal which passes through Kuachow is at normal times about 3 meters in depth. With a little dredging work to remove the shoals it will facilitate the navigation between Chinking and Yangchow. The estimate of the total expenses for this section of the canal including the construction of Shaopai Lock is given in the following:-

Construction of Shaopai Lock		$350,000
Excavation of the channel	888,790 cu.m.	119,986
Dike construction with excavated earth, ramming only	1,990 cu.m.	50
Dike construction with borrowed earth, ramming included	39,020 cu.m.	6,243
Total........................		$476,279

Total Cost of Navigation Project for the Grand Canal

The total cost for the first period of development are:

Section	Lock Construction $	Excavation of the channel $	Dike Construction with excavated earth, ramming only $	Dike Construction with borrowed earth, ramming included $	Reconstruction of rails and bridges. $	Total $
1st		967,705	27,551	9,209	50,000	1,054,465
2nd	300,000	445,535	13,896	322,537		1,081,968
3rd	400,000	334,391	14,249	316,499	50,000	1,115,139
4th	400,000	297,956	4,250	12,908		715,114
5th	400,000	89,920		12,800		502,720
6th	350,000	119,986	50	6,243		476,279
Grand Total	1,850,000	2,255,493	59,996	680,196	100,000	4,945,685

Article 3. Canalization of Rivers from Huaiyuan to the Sea.

The object of this project is to have direct navigation from the Upper Huai River to the Yellow Sea, by way of the Huai River, Hungtze Lake, Changfu Ho, Yen Ho and Kwan Ho. In the first period of development, it is proposed to start from Huaiyuan down the Huai River, passing the towns and cities such as Pengpu, Shuyi, Kaokiangchien, Matou, to Huaiyin, where it passes through the lock and through a new cut to Hsipa to join the Yen Ho. Another lock will be situated at Tsaikung on the Yen Ho. At Lungkou not far downstream of Tsaikung the navigation route divided itself into two courses, one passes over the Lungkou Lock to the Kwan Ho and find its way to the sea; another goes along the Yen Ho in the northern direction to the Shinpu Lock and then joins with the sea estuary of the Shu Ho. The total length of the navigable rivers will be 483 km. Besides the Huaiyin Lock, which will serve both the navigation of the Grand Canal and that of the present river system, three more locks will be constructed, i.e., Tsaikung, Lungkou and Shinpu Locks.

The Kwan Ho is exceptionally deep and wide, able to be directly navigated by coastal steamers of five-meter draft, up to Shiangshuikow. In future, if improvement work be executed, and jetties be constructed at the estuary to deepen the southern pass near Kaishan, it is possible to be navigated by ocean ships, and Shiangshuikow will be developed as a seaport.

In the Yen Ho near Lungkou, two movable dams will be constructed to prevent flood water of the Yi Ho from entering into it. These dams can be taken away after the levees along the portion of the Yen Ho from Tsaikung to Shinpu being raised to the required height. But for the time-being these dams will be closed when there is a high flood of the Yi Ho. Since the flood of the Yi Ho is short-durated, it would not be a tedious obstruction to navigation. At the side of the Lungkou Lock on the Kwan Ho, a larger movable dam is needed for preventing water of the Yi Ho from escaping into the Kwan Ho during the dry season. Owing to the project for improvement of the Yi Ho is not definitely determined, it is not wise to construct a permanent structure for this dam, because, in case detention basin can be economically constructed at its headwaters, the flood flow passed through this dam will be greatly reduced. Hence in the first stage of development, only earth-weed dam of the types commonly used as the flood escapes on the Inner Grand Canal will be built there.

The southern Liutang Ho is comparatively deeper than the Yen Ho, and with the completion of the Shinpu and Lungkou Locks, navigation will extend to the town of Kaokou on it.

For irrigation purpose a canal should be constructed between Kaoliangchien and Ching Ho Chai with a sluice at the mouth of the outlet, and in future a lock is to be built by the side of the sluice gate, so that boats coming from the upstream of the Huai River can sail to the Inner Grand Canal through this new course.

As to the tbibutaries of the Huai River excavation and installation of locks will further facilitate the navigation.

In future during the irrigation season the elevation of water surface of the Hungtze Lake may be reduced to 11 meters, but before the time when the consumption of water for irrigation purpose is at the highest degree, the lowest water level may be higher than 11 meters, so the excavation of the Hungtze Lake can be temporarily left undone.

Figures 24 and 25 cleary show the plan and profile of the scheme to be done during the first period of improvement for the Huai River and Figures 19 and 26 show the way of connection of the Huai River with the Grand Canal.

First Section: from Huaiyuan to Huaiyin Lock

Along this section of the Huai River there are many large cities such as Huaiyuan, Pengpu, Wuho, Shuyi and Huaiyin. Its importance of communication and benefit to traffic is known to all. At the upper part of this section, which is the middle part of the Huai River, the channel is both deep and wide, so a little excavation work will sufficiently accommodate the navigation of the biggest standardsized boats. At the railway bridge of Pengpu where the Tientsin-Pukow Railway line runs across the Huai River, the elevation of the abutments is much higher than the assigned high water level, so no reconstruction is necessary. From Kweishan to Kaoliangchien is the Hungtze Lake. It is quite shallow; so a new navigation course should be excavated.

From Kaoliangchien to Matou is the Changfu Ho, where works of excavation are quite limited, and below Matou there will be two new courses to join the Changfu Ho with the Huaiyin Lock and Middle Grand Canal (See Fig. 26.) The length of river for this section is 265 kilometers and the estimate of the total expense is given in the following:-

Excavation of a new channel in the Hungtze Lake	1,000,000 cu.m.	$160,000
Excavation of the channel	3,394,602 cu.m.	458,271
Dike reparation with excavated earth, ramming only	993,310 cu.m.	24,833
Dike reparation with borrowed earth, ramming included.	2,255,950 cu.m.	360,952
	Total.................	$1,004,056

The Second Section: from Huaiyin Lock to Tsaikung Lock

There is no means of direct communication between the Grand Canal and the Yen Ho at present. Any cargo coming from the Yen Ho are to be unleaded at Hsipa and transported to Huaiyin or Yangchuang for further conveyance on the Grand Canal, and any cargo coming from the Grand Canal are to be unloaded at Huaiyin or Yangchuang and transported to Hsipa for further conveyance on the Yen Ho. But Hsipa, Huaiyin and Yangchuang are several miles away from each other, so the unnecessary removal of cargo among those places not only wastes money and time but also causes much inconvenience. Now from the west of Huaiyin to the east of Hsipa, a new navigation channel for a length of 5.34 km. is proposed to be excavated to connect the Grand Canal with the Yen Ho.

Since the old channel Yen Ho below Hsipa is quite deep, it is still adopted for navigation and no more excavation is needed, but during the irrigation season, thewater surface of the Yen Ho between Huaiyin Lock and Tsaikung Lock will be raised higher than usual, so the dikes along this portion of the river should be strengthened and repaired. The expense for dike reparation which is to be included in the cost of irrigation project and the construction of Huaiyin Lock on the Grand Canal is also excluded from the present estimate.

The lowest water level at this section is 6.8 meters and the highest water level, 7.3 meters, and during the irrigation season the water surface below Huaiyin Lock will be raised to 10 meters and above Tsaikung Lock, to 9.9 meters. Below Tsaikung Lock the water level will be from 3.0 to 3.5 meters, so the maximum lift at Tsaikung Lock is 6.9 meters and the minimum, 3.3 meters. The length of river for this section is 61 kilometers and the estimate of the total expense is given in the following:-

Construction of Tsaikung Lock		$300,000
Excavation of new channel	2,125,680 cu.m.	286,967
Dike construction with excavated earth, ramming only	4,130 cu.m.	103
Total		$587,070

The Third Section: from Tsaikung Lock to Shinpu Lock

The variation of water level for this section of the river is 0.5

meters, that is, the highest water level is 3.5 meters and the lowest water level, 3.0 meters, but at Lungkou where Yi Ho flows to the Yen Ho through the Northern Liutang Ho, thehighest water level of the Yi Ho is 8.0 meters, and the lowest water level gives an insufficient depth of water for navigation. At Lungkou, two small movable dams should be built across the Yen Ho to keep out the flood water of Yi Ho and on the Kwan Ho a large movable dam made of weeds and earth should be constructed. At normal times this movable dam is closed to prevent the Yen Ho from flowing out, and during the flood season it is opened to discharge flood water of the Yi Ho. In future when Yi Ho is under improvement, a permanent movable dam is to be constructed to replace this temporary structure.

The water level above Shinpu Lock is from 3.0 to 3.5 meters and below it is from -2.2 to 3.35 meters, so the maximum lift at Shinpu Lock is 5.7 meters, but during the flood period of the Shu Ho, the water level below Shinpu Lock will be raise to 3.8 meters, being 0.3 meters higher than the high water level of this section. At that time Shinpu Lock is to be opened to give a free passage of the flow.

With the completion of the navigation works for the Huai River, Kwan Ho kow and Linhungkow will become the important sea ports both for the ocean steamers and for the transportation of freight to inland towns and cities. As to seaward bound cargo coming from those inland towns and cities, they can also be directly conveyed to either Kwanhokow or Linhungkow.

The length of river for this section is about 77 km. and the length of Kwan Ho from Lungkou to Kwanhokow is about 73 kilometers. The estimate of the total expense is given in the following:-

Construction of the Shinpu Lock		$300,000
Construction of lock on Yi Ho at Lungkou		300,000
Construction of a movable dam on Yi Ho at Lungkou		100,000
Construction of two movable dams on Yen Ho at Lungkou		100,000
Excavation of the channel	189,042 cu.m.	25,521
Dike reparation with excavated earth, ramming only	20,205 cu.m.	505
Dike reparation with borrowed earth, ramming included	30,469 cu.m.	4,875
Total		$830,901

Total Cost

The total expenses of navigation projects for the Huai River to the sea are given in the following:-

Number of section	Construction of lock $	Construction of movable dam $	Improvement of channel $	(a) $	(b) $	Total
1st			618,271	360,952	24,833	1,004,056
2nd	300,000		286,967		103	587,070
3rd	600,000	200,000	25,521	4,875	505	830,901
Grand total	900,000	200,000	930,759	365,827	25,441	2,422,027

(a) Dike Reparation and construction with borrowed earth ramming included

(b) Dike Reparation and construction with excavated earth ramming only

The excavation of a new navigation channel in the Hungtze Lake is to be postponed until the time when the consumption of water for irrigation purpose is increased and the lowest water level of Hungtze Lake is reduced to less than 12 meters. The expense of excavation which amounts to $160,000 should be reserved for this item.

Chapter IV. Irrigation Project

The region on both sides of the Old Yellow River and the Grand Canal comprises a large area of fertile land with temperate climate quite suitable for cultivation. It is really one of the important sections for agricultural production in our country. But so long as the flood problem of the rivers, such as the Huai, Yi, Shu and Sze which drain in that region, remains not solved, the inundation and drought will constantly occur that famine can never be prevented. Hence as soon as we have proposed the projects for flood control in order to remove the harmful elements of that region, we are able to propose the projects for irrigation.

Article 1. Estimation on Requirement of Water

On account of the difference in soil characteristics, climatic conditions and customs of the people, the crops raised on both sides of the Old Yellow River are not identical. On the northern side the common crops raised are those which need less quantity of water for their production. In case of an extraordinary drought, it will nevertheless still subject to famine. Hence irrigation is also indispensable. On the southern side, rice is probably the only principal kind of crop to be raised, especially in the district east of the Inner Grand Canal. It needs much water for the production. During the irrigation season from later spring to summer, when the precipitation is small in magnitude, it depends wholly upon the Grand Canal for the supply of water. In case the supply of water in the Grand Canal from the Hwai fails, it is usually not suffici-nt for supplying the whole district. Hence the development of irrigation system is cryingly needed especially in this part of the country.

<u>CROPS RAISED</u> In the region at the south of the Old Yellow River the principal crops raised are rice, cotton, bean, wheat, sesame, pea-nut, potato, etc. The first mentioned two are the principal crops which need irrigation during the dry season from later spring to summer.

<u>PRECIPITATION</u> Long record of precipitation in the irrigation district is not available. Based upon investigations on monthly maximum, average and minimum precipitation from the record of short period at different places, it is indicated that in the year of average precipitation the water is just sufficient for crops, and that in dry year the precipitation amounts only to 4 inches (or 10 cm) from the middle of April to that of July. In thelatter case, rain water isnot sufficient for production of crops and hence irrigation is necessary.

NET QUANTITY OF IRRIGATION WATER NEEDED In spite of the minor products in the winter, the only principal crops which need irrigation are rice and cotton. The irrigation season for rice is generally from the middle of April to that of July, while cotton needs much water in the months of April and May. In order to obtain the maximum yield of rice, it will consume enormous quantity of water. But for average production, the amount of water needed for irrigation will not be much. Now let us take the case of 1922 for instance. The yield of rice in the Eastern District of the Inner Grand Canal in that year was on the average more than two piculs per mou (30 kg. per are or 3,000 lbs per acre). A portion of land which is comparatively low in elevation was irrigated by the supply of water from the sluices located in the eastern dike of the Grand Canal, while the remaining portion in this region had its supply of natural precipitation only. During the period from the middle of April to that of July, the precipitation amounted to 8 inches (20 cm) approximately, and the water supplied by the Grand Canal according to our investigation was about 95 cubic meters per second, amounting to a total quantity of 735,000,000 cu.m. The average of rice field in this district according to the Kiangsu Grand Canal Board is about 10,000,000 mou. Assume one third of the land was irrigated by water of the Grand Canal; then its average supply including all losses was about 14 inches (35.5 cm). The total consumption of water in that year was therefore, from 8 to 22 inches (20 to 56 cm). The yield of rice per mou was from 1.5 to 3.5 piculs. Based on this investigation, if some one foot (30.4 cm) of water be supplied by irrigation system, it would be sufficient to prevent famine even in case of extraordinary drought. Its production will naturally increase during the wet year. Hence a quantity of 18 inches (45.6 cm) of water may be considered necessary for rice production and half the value or 9 inches (22.8 cm) will be quite sufficient for cotton and other miscellaneous crops. During the irrigation season even in the dry year there is at least 4 inches (10 cm) of precipitation. Therefore the amount needed to be supplied by irrigation system is about 14 inches (35.5 cm) for rice field and 5 inches (12.7 cm) for cotton and others. The total amount of irrigation water can then be estimated on this basis.

CONVEYANCE The water carried in irrigation canals will be partly lost due to seepage and evaporation. The losses vary widely with local climatic conditions and the character of the bed of the canal. The quantity lost by evaporation is much less than that lost by seepage, while the loss in old canals is always smaller in comparison with the case of new canals. Now in the present irrigation distructs, the amount of losses is assumed to be 15% for old canals and 30% for new ones.

IRRIGATED AREA In the region at the south of the Old Yellow River, the land to be irrigated may be divided into four districts, namely:

1.) the Eastern District of the Grand Canal

2.) the District of the Hao Tao Lakes

3.) the District of the Tungyang Canal, and

4.) the Coastal District

The Eastern District includes all the land belong to the Hsiens of Kiangtu, Kaoyu, Paoying, Shinhwa, Tungtai, Taihsien and Yenchen. According to the estimation made by the Kiangsu Grand Canal Board, the area of this district, not including the land east of Fankung Dike, is about 11,740,000 mou, 86% of which is used for rice production and the remaining 14% is for other miscellaneous crops. The District of Kao Pao Lakes includes all the low land on the southeastern side of the Hungtze Lake and the west of the Grand Canal, that is, the land surrounding the Peima, Paoying, Kaoyu, Fankwan and Chiehshou Lakes, together with the reclaimed land. According to the estimation by the Kiangsu Grand Canal Board, there is approximately 1,840,000 mou of land between the highest stage and the ordinary water level of the lakes, and in addition another 1,000,000 mou of lake area can be reclaimed. After regulation of the Hwai River, assume 20% of the total area to be occupied by villages and towns, highways and canals, and then the land available for cultivation will be 2,250,000 mou (see chapter on flood control). But for cultivation of the land in this district, not only irrigation canals are indispensable, but drainage systems must also be taken into consideration. Since the land is very low, the accumulation of rain water will cause much trouble. For this reason drainage canals and pumping stations must be provided (See Fig. 29). Judging by its local conditions, there will be probably 80% of the land to be used for rice planting and 20% for other crops. The

District of Tungyang Canal partly overlaps with the Eastern District and the Coastal District, and partly depends its supply from the Yangtze. The additional land to be irrigated by the Grand Canal is about 2,500,000 mou, 30% of the land is of rice field, and 70% of it is for cotton and other crops. The Coastal District has an area of 5,000,000 mou approximately. During its progressive development in recent years cotton is almost the only kind of plants raised in this district. It demands less quantity of water for its production. But irrigation will be still necessary in case of drought during the months of April and May.

TOTAL AMOUNT OF WATER REQUIRED Based upon the foregoing discussions, the total amount of irrigation water needed for different districts may be roughly estimated. The Eastern District will demand a quantity of 2,670,000,000 cubic meters of water for irrigation in one year; the District of Kao Pao Lakes will demand 561,000,000 cubic meters; the District of Tungyang Canal, 351,000,000 cubic meters; and the Coastal District 512,000,000 cubic meters. The total annual demand for the land at the south of the Old Yellow River will then be 4,094,000,000 cubic meters.

Article 2. The Capacity and Elevation of the Hungtze Lake.

For the irrigation of the land south of the Old Yellow River, the flow of the Huai River will be the only source of supply. The natural flow of the Huai is very small in case of dry year. For instance in

1917, it almost entirely ceased to flow during the months of May and June. For meeting the demand of irrigation, the Hungtze Lake must be converted into a storage reservoir.

According to the record of the Huai, the year 1917 was the driest (see Fig. 37). The total amount of discharge during that year was still much greater than the demand of irrigation. Therefore if a portion of the flow during the flood season in stored up in the Hungtze Lake, it will be sufficient to meet the need in the dry season. In solving the problem of storage, two points must be taken into consideration. Firstly since the natural flow during the irrigation season can be directly utilized for partly supplying the need, the amount of water necessary to be stored in the lake will be somewhat less than that of the total demand. And secondly, because the lake has a large surface area, the quantity lost by evaporation will be considerable. Now for our case the total demand for irrigation is 4,094,000,000 cubic meters. Deducting the quantity of 1,370,000,000 cubic meters which can be supplied by the natural flow during the irrigation season, it amounts to 2,724,000,000 cubic meters. Assuming another 1,000,000,000 cubic meters lost through evaporation, the total amount of storage will be 3,724,000,000 cubic meters. If the allowed lowest lake surface elevation be 11 meters, then from the capacity curve (Fig. 1) it is found that the lake surface must be maintained at 13.2 meters after the flood season in order to meet the demand. For additional safety, let it be maintained at 13.6 meters after every flood season is over.

The Hungtze Lake is used as storage reservoir for irrigation, as well as a detention basin for flood control. In order to utilize its full capacity for detention so as to reduce the cost of the improvement work for its flood channel, the lower the surface elevation of the lake kept before the flood season, the better would be the case. But as for irrigation, the elevation of the lake surface must have a certain lowest limit so that the storage can be surely accumulated to the required quantity before the irrigation season. Considering the worst case of 1917, the amount of storage, which could be supplied by the flow of the Huai during the period after the flood and before the next irrigation season, was found to be 2,500,000,000 cubic meters. As the capacity of the Hungtze Lake between the elevations 13.6 and 12.5 meters is 2,200,000,000 cubic meters, it is concluded that the lowest allowable limit of the surface elevation of the lake during the flood season may be as low as 12.5 meters. This will render great efficiency in flood control and at the same time no obstruction for irrigation.

In conclusion, for purpose of both irrigation and flood control, the W.L. of the Hungtze Lake before the flood season must at least be higher than 12.5 meters, and it must reach the elevation 13.6 meters before the next irrigation season.

Article 3. Distribution of Water for Irrigation

The topographical features of the land within the irrigation districts have a general tendency to slope down from north to south. The Inner Grand Canal and the Chuangchang Ho are also flowing in this direction, and their water surface is generally higher than the surrounding countries. Hence for the convenience and distribution of water during the irrigation season, they can be utilized as the main irrigation canals, but the way of supplying water to them from the Hungtze Lake is a problem worthy to be considered.

The Changfu Ho, an outlet of the Hungtze Lake, is used to supply water to the Grand Canal from the lake. At its north extremity where it joins with the Inner Grand Canal, its water surface is higher than the surrounding countries, so it may be utilized as a main irrigation canal. But its channel is very narrow and the land along the two banks is very high. After the installation of a lock at Huaiyin for the navigation of the Huai River and the Grand Canal, the discharge of the Changfu Ho, during the time when the water level of the Hungtze Lake is 12 meters, will be about 50 cubic meters per second, and when it is raised to 13.6 meters, will be about 140 cu.m.per second. But in average the total volume of water needed for all the irrigation districts is 475 c.m.s.. In order to supply the necessary volume of water, the Changfu Ho should be deepened and widened, but the narrowness of the channel and the elevation of the two banks will render the excavation works too expensive to be executed as the main irrigation canal. According to the opinion of Prof. Otto Franzius, a great portion of water needed for irrigation should be conducted to flow from Kaoliangchien passing through the old channel of Hsun Ho to Chinghochai on the Grand Canal. Though the old channel of Hsun Ho is also quite narrow, yet the land along its two banks is very low, so excavation and dike construction with excavated earth can be done at the same time and the expense will be much cheaper. As to the Changfu Ho, its existing capacity can still be utilized for irrigation.

The volume of water necessary for the cultivation of crops at each of the irrigation districts during the hundred days of irrigation season is as follows:-

For the Eastern District	310 cu.m.per sec.
For the Kao Pao Lake District	65 cu.m.per sec.
For the Tungyang Canal District	40 cu.m.per sec.
For the Coastal District	60 cu.m.per sec.

The total volume of water consumed by the cultivated farms of the above districts amounts to 475 c.m.s.. But during the month when water is most needed for the fully cultivated districts, the volume of water actually consumed may be greater than this value. This condition will, however, not be occurred until after 10 or 20 years, and during that time further improvements will be made. At present the estimate for the discharge of themmain irrigation canal can base on the average rate.

Now the discharge of the main irrigation canal which flows from the Hungtze Lake to the Grand Canal through the Ching Ho Chai is assumed to be 425 c.m.s. and a small volume of water equal to 50 cubic meters per second is conducted to flow from the Changfu Ho to the Chuangchang Ho passing through the Yen Ho to Tsaikungtu and crossing the Old Yellow River to its south. As to the portion of water flowing to the Grand Canal at Ching Ho Chai, a volume equal to 25 c.m.s. is conducted to flow northward to irrigate the cultivated farms situated along the northern bank of the Grand Canal and another volume equal to 100 c.m.s. is conducted to flow eastward to Chuangchang Ho passing through Ching Ho and crossing Sheyang Lake to irrigate the cultivated farms along the two banks of the river and to supply the Chuangchang Ho with remaining water, while a great portion of water equal to 300 c.m.s. is conducted to flow southward to irrigate the cultivated farms of the Kao Pao Lake District and the Eastern District at the south of Sheyang Lake with the remaining water equal to 40 cu. m. per second flowing to Tungyang Canal through Chaopai to irrigate the cultivated farms of the Tungyang Canal District. The volume of water which flows from the Changfu Ho to Chuangchang Ho through the Yen Ho is used to irrigate the cultivated farms situated between the south of the Old Yellow River and the north of Funinghsien with remaining water flowing to Chuangchang Ho to join with the canal coming from Ching Ho and to irrigate the Coastal District. This is the method of distributing water to the irrigation districts in our irrigation project.

Article 4. Irrigation Canals

During the irrigation season, the water surface of the Hungtze Lake will be drawn down from the normal elevation of 13.6 meters to the lowest level of 11 meters. This lowest water level will be reached only during the most arid season and in a very short duration of time, and moreover the time of its occurrence will be mostly at the closing period of the irrigation season. During that time the flow of the irrigation canal will be left to itself, that is, drawing down to its limit, for otherwise, it requires expensive construction work in the sluices and canals. It is also very expensive to make all the irrigation canals used at the same time as navigation canals as in the case of the Inner Grand Canal. Moreover during the dry season, the water surface will be lowered, so even there may be plenty of water in the channel, yet it is very difficult to distribute it to the irrigation districts.

The irrigation canals are to be so designed that during the time when the water surface of the Hungtze Lake is at an elevation of 12 meters, they should give the maximum discharge for irrigation, and when the water level is lowered, the discharge is allowed to be less in quantity. At normal times the water level of the Grand Canal at Ching Ho Chai is 6.8 meters, and during the irrigation season, it will be raised to 10 meters. The length of the channel from the Hungtze Lake to Ching Ho Chai is 40 kilometers, and the slope of the water surface is 1:20,000. Now a channel to discharge a volume of water equal to 425 c.m.s. can be designed by the Forchheimer's Formula with a coefficient of roughness of 0.0225. The resulted cross section is as follows:-

Width of water surface	= 75 meters
Width of canal bottom	= 45 meters
Depth of water	= 8 "
Side slopes	= 1:2

The best cross-sectional design of the channel is to make the cut and fill in balance, that is the quantity of excavated earth is just enough for dike construction. The quantity of excavated earth used for dike construction is 7,500,000 cu. m. and the expense for both excavation and dike construction is about $1,200,000.

As the quantity of water in the Grand Canal which flows northward from Chinghochai is only 25 c.m.s., the existing width of the channel is quite enough for its discharge and another volume of water equal to 300 c.m.s. flows southward in the Grand Canal from Chinghochai with a remaining quantity of water equal to 40 c.m.s. flowing to Shaopai. The water level of the canal at Shaopai Lock can be reduced to 6 meters, so there will be no obstruction for navigation. As the length of the channel from Chinghochai to Shaopai is about 100 km. and the difference of water level is 4.0 meters, the average slope of the water surface will be 1:25,000. Now with the diversity of discharge and different size of channel at each section of the irrigation channels, it will be economical to make the slope of the water surface steeper at those places where the cross-section of the channel is small, and to make the slope of the water surface flatter at those places where the cross-section of the channel is large so as to save the labor of excavation to its utmost limit. According to the cross-sections of the Inner Grand Canal surveyed by the Liang Huai Conservancy Board, the channel from Fanshui to Kaoyu is both narrow and shallow and needs to be excavated, and for the rest of the canal the channel is wide enough to carry the allotted quantity of discharge. With the rise of water surface due to the construction of locks at each section of the canal, the top of the dikes from Huai-an to Fanshui should be raised about one meter higher. Now the quantity of earth for dike reparation is 472,500 cu.m., and if the labor of ramming for one cu. m. of earth is $0.16, the total expense for dike reparation will be $75,600. The quantity of excavated earth is 2,527,600 cu. m. and if the labor of excavation for one cu. m. of earth is $0.27, the total expense for excavation will be $682,000. The summation of these two items will be $757,600.

Water in the Grand Canal flows eastward from Chinghochai to Chuangchang Ho and the height of water surface at the eastern extremity of the irrigation channel which joins the Grand Canal with Chuangchang

Ho depends upon the volume of water flowing southward from Yen Ho to Chuangchang Ho and the height of water surface at Chuangchang Ho necessary for irrigation. Now if the height of water surface at the eastern extremity of the irrigation channel is assumed to be 5 meters, and that at the down-stream side of the Chinghochai, 7 meters, that is, the difference of water level between the upper and lower pools of the Chinghochai is 3 meters, the difference of water level in the irrigation channel will be 7.0 – 5.0 = 2.0 meters. The length of the channel is about 84 kilometers, so the slope of water surface will be 1:42,000. The most economical cross-section is as follows:-

Width of water surface	= 40 meters
Width of channel bottom	= 12 "
Depth of water	= 7 "
Side slopes	= 1:2

The quantity of excavated earth is 14,000,000 cu.m. and the cost $2,240,000.

The Changfu Ho and Yen Ho are not to be excavated and with their existing discharge capacity, the discharge of Yen Ho above the proposed Tsaikung Lock will be about 50 c.m.s. during the time when the height of water surface at Hungtze Lake is 12 meters. When the water level at Huaiyin Lock is maintained at 11 meters, it will be reduced to 9.93 meters at Tsaikung Lock, and such height of water surface gives no obstruction to navigation. The length of the irrigation channel starting from the Yen Ho at Tsaikung Lock and crossing the Old

Yellow River to Funing to join the Chuangchang Ho is about 48 kilometers. If the water level of Chuangchang Ho at Funing is 6.0 meters, the slope of the water surface will be 1:12,200. The cross section best adopted for the irrigation channel is as follows:-

Width of water surface	= 25 meters
Width of channel bottom	= 5 "
Depth of water	= 5 "
Side slopes	= 1:2

The total amount of excavated earth and earth used for dike construction is 6,720,000 cu.m. and the cost will be $1,110,000.

At Shaopai the volume of water in the Grand Canal is only 40 cu. m. per second, which flows from Shaopai to Liuchai to join the Tungyang Canal. At Liuchai the old structure should be reconstructed and the cost is estimated to be $50,000.

The dimension of each irrigation channel is based on the plans prepared by the Kiang Huai Conservancy Board, so after an accurate survey is completed, the design is likely subject to change.

The diversion and distribution of irrigation water are effected by regulaters and sluices, their locations can only be ascertained by the local conditions and requirement. This is left for further investigation. In the sea outlets of the Chuangchang Ho and the by passes to the Yangtzekiang on the Tungyang Canal should also be controlled by movable dams or gates. They will be dealt with after careful survey is completed. Besides these, there will be five head-gates to be constructed for the irrigation channels and the costs are estimated to be $600,000.

Article 5. Irrigation in the Middle Grand Canal District.

At the north of the Old Yellow River and both sides of the Middle Grand Canal, most of the crops such as wheats, beans, holcus, potatoes and other grains donot require much water. At these places, irrigation is unknown to the farmers. It is mostly caused by natural lack of water supply.

When the Hwai River, Yi Ho, Sze Ho and Shu Ho have been controlled and improved, the Wishan Lake will be converted into a natural reservoir. Its storage of water amounting to some 2,400 million cubic meters will be used to irrigate the arid regions covering an area of 20,000,000 mou in the districts of Hsuchow and Haichow. Now the Middle Grand Canal and Pelao Ho can be utilized as the irrigation channels. The discharge of the Pelao Ho with a high water level at the Wishan Lake is about 100c.m.s., and the remaining quantity of water necessary for irrigation is to be conveyed by the Middle Grand Canal. As the canal is also used for flood discharge, so its capacity is ample enough for conveying irrigation water. At Yeshenchai and Hotingchai, there are movable dams for the regulation of flood discharge, and at Liulauchien a movable dam should be constructed to discharge the necessary quantity of water for the cultivated farms situated at the lower course of the canal; The cost is estimated to be $25,000.

Article 6. Works for the First Stage of Development.

Due to the vastness of irrigation districts, all irrigation works cannot be done at the same time, and as the engineering works for flood discharge, navigation and irrigation bear intimate relations with each other, so any work for the benefit of one thing should keep pace with that of the other. When the engineering works for controlling the Huai River to flow to the Yangtze River are in progress, some improvements should be made for the irrigation districts at the south of the Old Yellow River as the foundation of development. The most important region under consideration is the Eastern District of the Inner Grand Canal, where there are numerous lateral head works built in the eastern dikes, but due to improper management, much water is wasted. Hence at each of the lateral head works, a proper sluice-gate should be fitted. The method of its operation and the allotted amount of water should be carefully determined according to the commanding area, kinds of crops, and the nature of soil. There should also be patrol men to take charge of these duties, and give assistance to the farmers in using irrigation water. With the assistance of the general public, the distribution system is expected to be finished in a few years. But in the Inner Grand Canal at the time of preliminary development, no harm is done if the discharge of the canal is smaller than the total volume of water needed for irrigation, so the dredging of the channel between Fanshui and Kaoyu can be temporarily postponed, and improvement is done simply by the installation of 50 sluice-gates, the cost being estimated to be $100,000. This is the preliminary project for the irrigation of the Inner Grand Canal district.

At the Kao Pao Lake district, if irrigation and drainage works are built after the improvement of the Huai River, about 1,000,000 mou of marshy land can be reclaimed. If the cost of one mou is $40, $40,000,000 will be obtained from reclamation, which will nearly pay for the expense for the preliminary engineering works of the Huai River system. If the irrigation and drainage channels of that district are constructed at the same time, the excavated earth from the drainage channels can be used for dike construction along the irrigation channels. The arrangement of the irrigation and drainage channels are shown on Fig. 29. Their discharge capacities, cross-sectional areas, and excavation have been carefully investigated, and the expense of the engineering works is given in the following:-

Dike construction with excavated and borrowed earth, ramming included	3,341,000 cu.m. @ $0.16/cu.m.	$ 535,000
Excavation of channel	17,863,000 cu.m. @ $0.135/cu.m.	2,412,000
Land occupied by channels to be purchased	9,500 mou @ $20/mou	190,000
Lock and sluice construction		460,000

Installation of five pumping plants $1,000,000

Total........................ $4,597,000

The irrigation channel which is used to convey water from the Hungtze Lake to the Inner Grand Canal is one of the most important canals and its excavation will attract our first attention. For the sake of everlasting safety, the channel should have a discharge capacity of 425 c.m.s.. The new outlet of the Tungyang Canal should also be excavated so as to give no obstruction to the water source. Their designs and costs of excavation have been already discussed.

The following table is a summary of costs and works for the first stage of irrigation development.

Table 7. Estimates of Costs for Irrigation Projects.

Items	Estimates of Costs.				
	Excavation of channel	Structure	Purchasing of land	Installation of pumping plants	Grand Total
Irrigation channel (from Hungtze Lake to Chingho-chai)	$1,200,000	$300,000			$1,500,000
Installation of sluice-gates on the Inner Grand Canal		100,000			100,000
Irrigation and drainage works in Kao Pao Lake District	2,947,000	460,000	$190,000	$1,000,000	4,597,000
Outlet for the Tungyang Canal		50,000			50,000
					$6,247,000

The benefits of irrigation towards agriculture is so great that besides the $40,000,000 obtained from the reclamation of the Lao Pao Lake District, the value of the yearly crops at that district will be worth about $10,000,000. At the Eastern District, the area of the land to be irrigated is approximately 10,000,000 mou. If 5,000,000 mou are under irrigation at the beginning and the minimum return of one mou is $2.0, then $10,000,000 will be gained yearly from that district. Hence the benefit of the preliminary engineering project towards the wealth of the people is so great that its accomplishment should not be delayed.

Chapter V. Works to be Performed

Construction works of flood control, navigation and irrigation for the whole system of the Huai basin are numerous. For those which is of primary importance, general schemes have been already laid down; and for the others, it remains to be investigated. The Engineering Bureau is preparing on one hand to carry out the construction works of the primary importance, and on the other to work out the definite projects, at the same time, for the construction works to be performed in the following years. Further investigations on economical selection and detail design are also necessary for the works to be carried out in the first few years. According to the general schemes laid down in the foregoing chapters, a list of works to be performed for surveying, designing and experimenting is scheduled as follows:-

(A) WORKS FOR SURVEYING:

1. The upper valleys of the Yi and the Shu River;
2. The Weishan Lake and the Grand Canal in the Province of Shantung;
3. Lakes in the upper valley of the Huai River;
4. Precise levelling along the Grand Canal and the Huai River;
5. Topographical survey of the different sites of the proposed straight cuts on the upper Huai and its tributaries;
6. The proposed navigation channel to connect the Inner Grand Canal to Hungtze Lake from Kaoliangchien to Chinghochai;

7. The proposed navigation channel between the Yen Ho and Chuangcheng Ho;
8. The proposed navigation channel fromChinghochai on the Inner Grand Canal east to the Chuangcheng Ho;
9. The sites for locks and sluices on the outlets of the Chuangchang Ho to the sea and on that of Tungyang Canal to the Yangtze;
10. The sites for locks on the Middle and Southern Grand Canal in Shantung;
11. Topographical survey of the Lihowa and the proposed cutoff of the Huai at Shuangkou
12. The sites for lock and dam on the Huai River at Fushan;
13. To establish more hydrological stations on different rivers in the Huai Basin; and
14. To connect the levelling lines on both banks of the Yangtze River.

(B) WORKS FOR EXPERIMENTING:

1. Soil exploration on the proposed sites of structures;
2. Test of bearing capacity of soil at the different sites for structures;
3. To establish the hydraulic laboratory for the experiment, by models, to predict the conditions of structures after construction;
4. Experiment by models the stability of the proposed river course

and channel sections;

5. Expeiment by models the percolation in earthern dikes;

6. Inspection and test on building materials; and

7. Actual measurement for determining Kutter's coefficient of roughness of river bed.

(C) WORKS FOR DESIGNING:

1. Selection and design of construction plants and equipment;

2. The field layout of construction;

3. Regulation for field offices and specifications for structures;

4. Provision of means of communications for different construction camps, and care for the living of laborers;

5. Detail designing for locks and movable dams;

6. Project on the systems of detention basins on Yi and the Shu rivers;

7. To design the navigation canal from the Weishan Lake to connect with the Yellow River;

8. Project for the improvement of navigation system in the Tung-yang Canal;

9. Projects for regulation of the sources of the Huei River in the mountainous valleys;

10. Projects of local systems in drainage, irrigation and reclamation of lands for different districts;

11. Designing highways and bridges;

12. Different city-plans and harbor-plans such as Huaiyin, Chiang-

shuikow, Kwanhokow and Sankiangying;

13. Planning of machine shops for repairing instruments and equipments used for construction;

14. Further investigation on the operation of the Huangtze Lake so as to reduce its maximum surface elevation; and

15. Rules and regulations for administration and maintenance of the completed structures.

Ceographical Names in English and Chinese

A

Ancient Canal, the

Anhuaichih

Chaimee Ho

Changfu Ho

Chaochiachih

Chenyangkwan

Chiang Ho

Chichih

Chienchiachih

Chienshu Ho or
Front Shu Ho

Chiulungmiao

Chowchiakow

Chu Ho

Chunchiakow

Chungyichih

Ertaokow

Fankung Dike

Fanshui

A

Anhowa

C

Changchuang

Changkushan

Chentzewa

Chiangchiakou

Chiangpa

Chichshou

Chien Ho

Ching Ho

Chitsung

Chowhsien

Chuangchang Ho

Chulopa

Chungshin

E

F

Fankwan Hu

Fei Ho

Fenghwang Ho
Fengtai
Fengyang
Fengtaitze
Front Shu Ho
Funing
Fushanchia
Fushingchai

G

Grand Canal, the

H

Haichow
Hanchuang
Hei Ho
Hotingchai
Houchiu
Hsiangchiaochih
Hsiangchien Hu
Hsifei Ho
Hsin Ho
Hsinhochen
Hsinpu
Hsintukow
Hsinyangchiang
Hsipa
Hsuchow
Hsuhsien
Hsung Ho(Shun Ho)
Huai River, the
Huai-an
Huaiyin
Huaiyuan
Huchuangwei
Huiliuchih
Hung Ho
Hunghokow
Hunghwapu
Hungtze Lake, the

I

Inner Grand Canal
I-tsenchih

J

Ju Ho

K

Kaishan

Kaoliangchien

Kaotzutze

Kaoyu Lake, the

Kiangtu

Kingwan Ho

Kuachow

Kwan Ho

Kweishan

Kwo Ho

Kaokou

Kao Pao Lakes, the

Kaoyu

Koushangchih

Kingkouchen

Kotsitze

Kuan Ho

Kwantien Ho

Kwei Ho

L

Lichuang

Lihowa

Linhungkow

Liuchiakou

Liushupang

Lochiaochih

Lukow

Lunghochih

Lienshui

Lingchiapa

Lingpi

Liulauchien

Liutsekow

Loma Hu

Lukowpa

Lungkou

M

Main Liutang Ho

Maotsechuang

Meihokow

Mengyi mountains

Malangkang

Matou

Mengchen

Middle Grand Canal, the

Ming Dike

Montao Ho

N

Nan Hu

Nanliutang Ho or Southern Liutang Ho

Northern Liutang Ho

O

Old Yellow River, the

P

Paichiachien

Paichiawan

Paifangtaitze

Pakiangkow

Peifei Ho

Pei Ho

Peiliutang Ho or Northern Liutang

Peima Hu

Peito Ho

Pengpu

Pien Ho

Pihu Ho

Pochiatz

Pochow

Pelao Ho

R

Rear Shu Ho

Rose River, the

S

Salt Canal, the or Yen Ho

Sanchakow

Sanchatu

Sangchu Lake

San Ho

Sanhochien

Sanhokow

Sanhopa

Sanhotou

Sanhowei

Sanhuangchih

Sankiangying
Sanyang
Shachiafong
Shachiakow
Shakiang Ho
Shakouchih
Shaopai
Shatou Ho
Sheyang Hu
Shiangshuikow
Shih Ho
Shinanchen
Shinhwa
Shiukangchih
Shouhsien
Shuangkou
Shu Ho
Shuhsiang Hu
Shui Ho
Shungti Ho
Shuhhochih
Shutangchih
Shuyang
Shuyi
Siaoleechih
Sihsien
Sin Ho
Southern Grand Canal
Southern Liutang Ho
Sze Ho
Szehsien

T

Taichung
Tai Ho
Taihsien
Tanchen
Tanchiachien
Tangchia Lake
Tasha Ho
Tashitu
Tenghsien
Teshenchai
To Ho
To Hu
Tongchiakou
Tsaikungtu
Tsaochow
Tsaolingchih

Tse Ho	[illegible]	Tsematou	[illegible]
Tsingchungchih	[illegible]	Tsingtao	[illegible]
Tsingyi Lake	[illegible]	Tungchichai	[illegible]
Tungpai	[illegible]	Tungping	[illegible]
Tungtai	[illegible]	Tungwan Ho	[illegible]
Tungwashian	[illegible]	Tungyang Canal	[illegible]

W

Wanfuchih	[illegible]	Wanfu Ho	[illegible]
Weichiehai	[illegible]	Weu Ho	[illegible]
Wishan Lake	[illegible]	Wucheng Ho	[illegible]
Wuhohsien	[illegible]	Wuhwachiao	[illegible]

Y

Yangchow	[illegible]		
Yangchuang	[illegible]	Yangtu	[illegible]
Yangtzekiang	[illegible]	Yaowan	[illegible]
Yellow River	[illegible]	Yenchen	[illegible]
Yenchiachih	[illegible]	Yenweichiang	[illegible]
Yenwotze	[illegible]	Yi Ho	[illegible]
Yin Ho	[illegible]	Yinsheng	[illegible]
Yinsiaochih	[illegible]	Yungchen	[illegible]
Yunliuchai	[illegible]	Yuantu	[illegible]

Z

Ze Ka Wei	[illegible]		